Essays in labor economics

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ESSAYS IN LABOR ECONOMICS

- THESIS ABSTRACT -

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The importance of risk-sharing in agricultural economies has been extensively analyzed through the principal-agent framework, which predicts that sharecropping should be observed more frequently than fixed rent contracts when output uncertainty is higher. Empirical studies, however, provide mixed support for this prediction, since often fixed rent contracts are found to be prevalent in more risky environments. The first chapter provides a model where the relative incidence of share tenancy over fixed rent contracts may be negative depending, among other things, on the relative average degree of risk aversion of tenants and landlords.

The second chapter explores the empirical validity of the theoretical framework using Indian data. After paying special attention to the measure of uncertainty used to identify farming risk, a parameterized version of the theoretical model is structurally estimated. The econometric results support the proposed model.

The third chapter studies the offset effect of pension wealth on private wealth when individuals are misinformed about their future retirement benefits. We show that if individuals have expectational errors correlated with their actual pension wealth, and update over time their expectations, then the canonical econometric specification used so far to estimate the offset effect gives biased estimates. An alternative econometric specification is proposed and used to estimate the offset effect on Italian data. The estimates obtained are higher than the ones previously found in the literature.

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Chapter 1

Sharecropping and Risk-Sharing Revisited: A Competitive Approach to Contract Choice

1.1 Introduction

Farming activity is usually performed under three different arrangements. Under a *wage* contract a landowner hires a tenant to work under his direction; the tenant is paid a wage rate and the landlord keeps the entire output. Under a *fixed rent* contract the tenant manages farming activity directly, keeps all output, and pays a rent to the landlord for the use of the plot. Under a *share tenancy* contract the tenant farms the plot but keeps only a portion of the final output, the remaining output going to the landlord as payment for the land use.[1]

In the last two decades several attempts have been made to explain the determinants of contract choice and the rationale for the widespread practise of share tenancy in agrarian economies. Many studies take as a starting point that farming activity is intrinsically

[1]The literature usually refers to the tiller hired under the wage contract as a *wage laborer*, while it uses the term *tenant* in case of sharecropping and fixed rent contracts. To simplify we always refer to the contracting parties as tenant and landlord, regardless of the land contract. In the following the terms *share tenancy* and *sharecropping* are also used interchangeably.

risky and that a moral hazard problem may arise as the tenant may shirk effort, if not monitored. The effect of uncertainty on contract choice is then studied using the Principal-Agent framework, that embeds a trade-off between incentive provision and insurance by the landlord (principal) for the tenant (agent). This set up predicts that, as the exogenous uncertainty related to farming increases, the risk-sharing motive dominates the incentive one, and share tenancy should be observed more frequently than fixed rent contracts, as the former partially insures the tenant.

Some predictions of the Principal-Agent framework are, however, at odds with empirical evidence. First, there is mixed support for its predictions regarding the effect of farming risk on contract choice. A few studies have found a negative empirical relation between crop risk and the incidence of sharecropping (Rao, 1971; Allen and Lueck, 1999), while in others share tenancy seems indeed to be associated with riskier crops (Ackerberg and Botticini, 2000). A crucial problem affecting these empirical studies is that they use the crop cultivated on the plot to proxy for farming risk. The theoretical predictions, however, concern the relation between incidence of share tenancy and exogenous farming risk, i.e. uncertainty that cannot be affected by the agent's actions, while the crop cultivated may be chosen by the landlord or tenant. In Chapter 2 we analyze further this issue and propose a different measure of farming risk unrelated to the specific crop cultivated. Second, in agency theory typically the agent has no bargaining power in shaping the contract and determining the contract payments. These are set by the principal to maximize his profit, leaving the agent at his reservation utility. When applying this framework to agrarian contracts, the social situation economists have in mind is one where landlords and tenants are engaged in an exploitative relation, where the tenants are usually landless, and therefore powerless.

But such an asymmetric treatment of the economic power of landlords and tenants is not always realistic. Casual evidence on a number of agrarian societies shows that their tenants enter the agrarian contracts that best fit their needs, and that the tenant-landlord relation is far from being exploitative.[2] Finally, in the Principal-Agent framework the type of contract offered and the contract payments reflect the personal characteristics of the agents matched. This implies that we should observe a variety of contract payments within the same village, reflecting the heterogeneity in the social and economic conditions of the landlords and tenants. Contract terms, however, display a striking uniformity within village economies. There is overwhelming evidence showing that sharecropping contracts use the same output and input sharing rules within regions, despite differences in land productivity and personal characteristics of landlords and tenants.[3]

These arguments raise doubts on the general attitude present in the literature, that considers the Principal-Agent model as the valid framework to analyze *all* agrarian societies. As mentioned in Reid (1987), agrarian contracts are different ways to organize the management of a farm and we should not expect one theory of management to be valid over different periods and places. The purpose of the present paper is to propose an alternative framework to agency theory that may be more suitable for *some* agrarian economies.[4] We regard contract choice as an *occupational choice*. Both tenants and landlords are allowed to choose, among a given set of contracts, the one that maximizes their utility, taking as given the associated contractual terms (or payments). Because of heterogeneity in underlying

[2] See Sharma and Drèze (1996) and Jodha (1981) for India, and Burke and Young (2001) for US.
[3] See Burke and Young (2001) for a recent rigorous study using US data.
[4] Another departure from the principal-agent framework is found in Bell and Zusman (1976), where contract choice is studied using a bargaining model.

fundamentals (ability and risk aversion), agents self-select into specific contracts. Given the nature of the contracts, tenants and landlords decide whether to assume the cultivation risk and be "entrepreneurs", or to earn a fixed income, or to be "franchising" entrepreneurs and share the risk. The contract payments are then determined in equilibrium so that the choice of the landlord about which contract to offer is compatible with the preferences of the tenant in a general equilibrium sense, i.e. the demand of each contract type equals the supply.

In this framework, the relationship between purely exogenous risk and contract choice in equilibrium depends then on the elasticities of the agents' choices with respect to risk, which are functions of the agents' risk aversion. In general, an increase in farming risk shifts tenants' preferences towards the less risky contracts for the tenants (such as wage contract and share tenancy), while it shifts landlords' preferences in the opposite direction. The excess supply/demand generated are cleared for a given set of equilibrium contract payments, but the resulting distribution of contracts may entail a higher proportion of share tenancy over fixed rent contracts, as well as a lower one.

An additional difficulty in signing comparative statics with respect to risk arises from the fact that landlords' income under a share tenancy contract depends on the farming ability of the tenants they are matched with in equilibrium. Evidence from India shows that under share tenancy the tenant takes most of the farming decisions independently from the landlords, so that the final output depends on his managerial skills.[5] In our model, therefore, the landlords' decision of which contract to offer is affected by their expectations

[5]See Sharma and Drèze (1996) and Jodha (1981), where it is reported that even crop choice is left to the tenant, along with other important practical decisions, such as when to irrigate, harvest, etc. that ultimately affect the final output.

on the farming ability of the pool of tenants choosing share tenancy at the market contract rates. As higher exogenous farming risk selects more skilled tenants into share tenancy, such a contract becomes more attractive to the landlords with respect to the other two, as it pays a higher average income. This effect partly runs in the opposite direction of the pure risk effect mentioned earlier, as it increases the relative supply of share tenancy with respect to fixed rent contracts.

Apart from being able to predict the observed relation between risk and contract choice, the model proposed does not assume an asymmetric treatment of the bargaining power of landlords and tenants. Instead, it allows the tenants to obtain part of the economic rent generated by the contracts signed, due to the assumed heterogeneity in individual characteristics and uniformity in contract payments. As in a standard demand-supply framework, in fact, both sides of the market enjoy a surplus, excepting for the marginal agents, who are indifferent between a pair of contracts given the equilibrium payments.

The structure of the chapter is as follows. In section 2 we describe the main features of the model and discuss the validity of some assumptions, while in section 3 we formally present the model. Section 4 describes the properties of the demand/supply of contracts. In section 5 we find restrictions on the set of contract payments to ensure that all markets are active in equilibrium and in section 6 we prove the existence theorem for a competitive equilibrium in our economy. Finally, in section 7 we use a numerical example of the model to study the cases when a negative relation between risk and relative frequency of share tenancy over fixed rent contracts is likely to happen. Section 8 concludes.

1.2 The Competitive Framework: Overview of the Model and Related Literature

In this section we outline the model and its main implications. Farming can take place under three different contractual forms: wage contract, share tenancy contract and fixed rent contract. Landlords and tenants consider the payments associated with each of these contracts as given and respectively offer and look for the contract they prefer. In this sense agents are *price takers*, and payments are not individual specific. Tenants' outside option consists in wage labor in the urban sector.[6] Landlords' outside option is a non-farming activity.

Tenants and landlords are heterogeneous in their farming (or managerial) ability so that more skilled individuals are able to obtain higher output under those contracts where their managerial ability counts, i.e. share tenancy and fixed rent contracts for tenants and wage contracts for landlords. Agents are also heterogeneous in their risk aversion.[7] Given such heterogeneity in farming skills and risk aversion, tenants and landlords may have different preferences towards the contracts for given associated payments. Tenants with high farming ability and low risk aversion may prefer the fixed rent contract to the wage and share tenancy contract since it allows them to keep the whole output, and therefore obtain the returns to their skills. On the contrary, unskilled and highly risk-averse tenants will prefer the wage contract, where their remuneration does not depend on their farming (in)ability. Similarly

[6]The presence of a nearby town or city ties down the wage in the agricultural sector because if the wage was lower than the one offered in the urban sector, discounted by migration disutility, then farmers would prefer to abandon the villages and work in the urban sector.

[7]Eswaran and Kotwal (1985) also exploit the idea that the optimal contract may depend on the relative skills of the agents in supervising and managing the land. Though the qualitative prediction is close in spirit, the present model provides a substantially different framework, as they analyze a one-to-one principal-agent relation.

more skilled and/or less risk-averse landlords will prefer wage contracts. Share tenancy is then a way to match the preferences of tenants and landlords with intermediate farming skills and risk aversion.[8]

The selection of tenants and landlords in the different contracts conditional on the wage rate, the output share and the rent determines the demand and supply of each contract. Market equilibrium imposes that the payments have to adjust so that the offer of a specific contract from landlords equals the demand from tenants. For example an increase in the rent makes the fixed rent contract more attractive for landlords compared to share tenancy and wage contract, so that some landlords may switch, but it also makes the fixed rent contract less attractive for tenants who might therefore prefer share tenancy or wage contract.[9]

The framework outlined above has features that overcome the shortcomings of agency theory when applied to agrarian contracts' choice. First, as in a standard demand-supply framework, both tenants and landlords enjoy a surplus unless they are the marginal agents. The marginal agents are, in fact, defined as the tenants and landlords who are indifferent between a pair of contracts given the equilibrium payments, so that any agent who strictly prefers one contract over the others, conditional on the payments, is gaining an economic rent. This is in sharp contrast with the Principal-Agent model where the landlord gains the entire surplus, while the tenant is left indifferent between the contract offered and his

[8]Note that even though the present paper moves away from agency theory, it does not ignore the central issue of moral hazard, as landlords' farming ability may be interpreted as heterogeneity in opportunity cost incurred by landlords while monitoring wage laborers, who would otherwise shirk effort. In the empirical specification adopted in Chapter 2, landlords are indeed heterogeneous with respect to their monitoring costs.

[9]A similar framework could also be used to analyze housing contract choice. Home owners and hunters decide which market to enter, i.e. whether to sell/buy or rent a house, at the prevailing market prices. Heterogeneity in wealth, liquidity constraint and demographic characteristics whithin the two groups determines the demand and supply of houses in the two markets. Finally market prices adjust so that excess demands/supplies are cleared.

outside option.

Second, this set up has the potential to predict that sharecropping is less frequent than the fixed rent contract when output risk is higher and the only driving force is risk-sharing. When cultivation becomes riskier, the demand and supply of each contract change according to the preferences of the agents. More specifically if tenants are risk averse, then their demand shifts towards less risky contracts, i.e. from fixed rent to share tenancy and from share tenancy to wage contracts. Given this, the pool of tenants choosing share tenancy has on average higher skills, so that expected output under share tenancy increases and compensate for the increased uncertainty. On the contrary, risk-averse landlords shifts their preferences towards fixed rent and share tenancy contracts, but given the increased output under share tenancy, there is an absolute increase in the supply of share tenancy. Higher uncertainty may therefore be associated in equilibrium with a higher or lower ratio of share tenancy to fixed rent contracts, depending on the elasticities of the relative demand and supply with respect to risk. Such elasticities depend on the structure and the primitives of the model, and in particular on the degree of risk aversion of landlords and tenants and the sensitivity of output to the individuals' farming skills.

Finally, the assumption that all agents are *price takers* may seem questionable since landlords offer contracts and set the contractual terms, as argued by Singh (1989). The main point of this model, however, is that though landlords offer contracts and set the payments, they must compete for the tenants, i.e. they have to set payments so that there are tenants willing to accept the contract they offer at those terms. Such competitive pressure drives to zero excess demand/supply of the different contracts. It is therefore a long-run theory of equilibrium in the tenancy market, while it is silent about how agents search for the best option and how the equilibrium is reached. Price-taking behavior, however, may indeed explain why contract payments are typically not individual-specific in many agrarian economies. Under sharecropping contracts, output is usually split according to a fixed proportion (half-half, one-third, or two-third are the splitting rules typically observed), while under fixed-rent contracts the land is often rented out at a certain price per acre, regardless of differences in land productivity and personal characteristics of landlords and tenants, within a given economic region. The uniformity of contract terms has long been neglected by contract theory, and only recently have there been attempts to explain it. Young (1998) proposes a dynamic model where each contracting party forms expectations about the contract terms the opponent will demand, based on the contracts prevailing in the previous periods. Each party then proposes conditions likely to be accepted, as they were in the past. This explains how some terms and conditions of specific types of agrarian contracts are carried out over time, until they become conventions. Furthermore Young's model predicts that conventional contracts assigning payoffs in an egalitarian way (i.e. equally splitting the economic rent) are more stable over time as none of the contracting parties is extremely dissatisfied. In this respect, our model differs sharply from Young's approach. In the theory of conventional contracts, contractual terms emerge for each contract type independently of what terms and conditions are offered for other types of contracts. For example, to explain the emergence of customary sharing rules in sharecropping contracts, the wage and the rent are considered as outside options and therefore exogenous. In the present paper instead contractual terms are jointly determined for all contract types so that each agent is satisfied.

Note that in equilibrium landlords and tenants with complementary features are matched. Landlords with low farming ability and high risk aversion offer wage contracts and are matched with low skilled tenants demanding such contracts, and similarly high (intermediate) ability and low (intermediate) risk-averse landlords are matched with high (intermediate) ability and low (intermediate) risk-averse tenants under fixed rent contracts (share tenancy). The *positive sorting* displayed in equilibrium has characteristics similar to the sorting that arises in equalizing differential models, where workers with stronger preferences for certain job characteristics end up matching with firms providing jobs with those features, while wages adjust so that the demand and supply of jobs' types are equal.[10]

1.3 The Model

The economy consists of two types of agents: the landlords (L) and the tenants (T). Each landlord owns a plot of land and decides whether to manage directly farming activity on his plot by hiring workers through wage contracts, or to rent out the land through a tenurial contract (either a share tenancy or a fixed rent contract). We assume that landlords cannot mix contracts, i.e. they cannot divide the plot of land in smaller subplots and choose different contracts on each subplot.[11] Tenants do not own land, and decide whether to work as wage laborers, or rent in land and manage cultivation directly. We assume that tenants (or wage laborers) can work only under one landlord.[12]

[10] See Rosen (1986) for a clear exposition of the theory and its applications.

[11] In many agrarian societies where landowners own relatively small plots of land, or if they own large amount of land this is fractionated in smaller plots located in different areas, it is usually the case that the plot is rented out to one tenant. This assumption, however, may be restrictive for the *latifundia* economies characterized by landlords owning extensive land in a circumscribed area.

[12] If the tenant is allowed to rent in land from more than one landlord, then he would have the incentive to rent in land and spread the labor till the marginal product of land is equal to zero.

In general, a land contract is a pair (α, β) that specifies the share of output that the tenant may retain α, and the side-payment that the tenant receives from the landlord β. As usual, if $\alpha = 0$ and $\beta > 0$, we have the pure wage contract, where β is the wage paid by the landlord to the tenant. If $\alpha \in (0,1)$ and $\beta = 0$, we have the pure sharecropping system. Finally, if $\alpha = 1$ and $\beta < 0$, we have the pure fixed rent contract, where β is the rent paid by the tenant to the landlord for the use of the plot. We assume that there is a fixed number of contract forms, and all agents choosing a specific contract form are subject to the same conditions and terms, including the contract payments. To simplify, in the following we consider that agents can choose among three different contract forms, specifically a wage contract $W = (0, \beta_W)$, a pure sharecropping contract $S = (\alpha, 0)$ and a fixed rent contract $F = (1, \beta_F)$. Any agent choosing the wage contract, for example, is subject to the same wage payment β_W, and similarly all landlords and tenants choosing to enter a share tenancy contract accept α as the sharing rule. The underlying assumption is that landlords and tenants are price-takers. The analysis, however, goes through when K distinct sharecropping contracts are available, with associated payments α_k, $k = 1, ..., K$, provided that these share tenancy contracts differ in terms of side payments.[13]

We assume that tenants have the outside option of migrating to a nearby city and working in the urban sector at the competitive wage at no risk. The agricultural wage is therefore tied to equal the urban wage discounted by migration disutility, $\beta_W = w$.

Landlords and tenants are heterogeneous in their farming ability and risk aversion.

[13] As documented in Young and Burke (2001), the number of sharecropping contracts observed with positive frequency in village economies varies. In Illinois farmers usually sign share tenancy contracts involving a half-half, two-third or three-fifth rule. In West Bengal there is instead more variation, though in both cases the half-half rule is by far the most common.

Landlords are indexed by $m \in [0,1]$, and tenants by $n \in [0,1]$, so that higher values of m and n indicate both greater farming ability and lower risk aversion.

Output. On each plot of land, output is a stochastic function of the characteristics of the agent who manages the farm, hence of his index. We assume that under the wage contract farming decisions are taken directly by the landlords, while under share tenancy and fixed-rent contracts the tenant is the actual entrepreneur, and his farming ability affects the final output. It is a well established result in the literature that under share tenancy labor is underprovided as the tenant equates the marginal cost of farming (i.e. the wage) to his share of the marginal product, while under wage contract and fixed-rent contracts the entrepreneur (the landlord and the tenant respectively) obtains the entire output and efficiently chooses the amount of labor. In the general model of this section we abstract from input choice, but as we will show later the extension is straightforward; we therefore assume that labor supply is inelastic. Hence, output (Y) is given by

$$Y = \begin{cases} g(\varepsilon)\, y_L(m) & \text{if wage contract} \\ \\ g(\varepsilon)\, y_T(n) & \text{if tenurial contract} \end{cases} \tag{1.1}$$

where ε is the realization of a stochastic variable representing exogenous farming risk (related to weather, pests, etc.), and $y_L(\cdot)$ and $y_T(\cdot)$ are functions representing the effect on output of the farming ability of the agent who manages the plot, i.e. the landlord under a wage contract, and the tenant under share tenancy or fixed-rent contract. We assume that $y_L' > 0$ and $y_T' > 0$, and that $E(g(\varepsilon)) = 1$ and $Var(g(\varepsilon)) = \sigma^2$. Alternatively one may interpret the function $y_L(m)$ as the output obtained by the landlord under the wage contract net of monitoring cost incurred to ensure that the workers hired do not shirk effort. Landlords with greater monitoring ability would incur a lower cost, and therefore obtain higher output. Finally, we assume multiplicative uncertainty as previously done in the related literature.

The assumptions that: (i) landlords each own a single plot of land and tenants do not own land, (ii) agents cannot mix contracts, and (iii) the exogenous risk is perfectly correlated across different plots of land, ensure that the results of the analysis are not affected by the possibility of risk diversification through multiple contracts, possibly on plots with different exogenous risk. The focus of this paper is, in fact, on showing that share tenancy may exist in equilibrium even in a model where the only driving force is risk sharing.

Utilities. Let $u_L(\cdot; m)$ and $u_T(\cdot; n)$ denote the utility functions of a generic landlord m and tenant n respectively. Both functions satisfy the standard assumptions of continuity and concavity. Let $V_L(\alpha, \beta; m)$ and $V_T(\alpha, \beta; n)$ be the expected utilities as functions of the parameters of the contract. The expected utility of a tenant n under a generic contract (α, β) can be represented by the following function

$$V_T(\alpha, \beta; n) = Eu_T[\alpha g(\varepsilon) y_T(n) + \beta; n]. \tag{1.2}$$

The expected utility of a landlord m can be represented by the following piece-wise linear function of α

$$V_L(\alpha,\beta,n;m) = \begin{cases} Eu_L\left[g(\varepsilon)\,y_L(m) - \beta; m\right] & \text{if } \alpha = 0 \\ \\ Eu_L\left[(1-\alpha)\,g(\varepsilon)\,y_T(n) - \beta; m\right] & \text{if } \alpha \in (0,1]. \end{cases} \tag{1.3}$$

This function is discontinuous at $\alpha = 0$, i.e. at the wage contract, for the following reason. Under a wage contract the landlord manages the plot so that his farming skills affect the final output; his expected utility is therefore function of $y_L(m)$. Under tenurial contracts, he receives a portion of the output obtained by the tenant, so that his income under share tenancy and fixed-rent contracts depends on the output that the tenant n, with whom he is matched with, can obtain, i.e. $y_L(n)$. $V_L(\alpha,\beta,n;m)$ represents the expected utility of landlord m from contract (α,β) conditional on a specific level of tenant's ability, and the expectation operator is taken with respect to ε only, as in eq.(2). In choosing the contracts, however, landlords take into account the uncertainty related with the ability level of the tenant they are matched with, so that in comparing utilities across the available contracts, they formulate rational expectations on the pools of tenants choosing the different contracts. $V_L(\alpha,\beta;m)$ denotes the expected utility of landlord m from contract (α,β) conditional on the pool of tenants with whom the landlord may potentially match with.

1.3.1 Graphical Representation

In Fig.1 we plot α on the horizontal axis and β on the vertical axis. All points belonging to the positive part of the vertical axis are possible wage contracts; points belonging to the horizontal axis represent pure sharecropping contracts, i.e. with no side-payments;

and points on the locus $(\alpha = 1, \beta < 0)$ represent fixed rent contracts. Since $u_T(\cdot; n)$ is a continuous and concave function, and its argument is a positive linear function of α and β, $V_T(\alpha, \beta; n)$ is a concave function. For any tenant n the indifference curves on the (α, β)-plane are negatively sloped and concave. Given α (or β) tenants' utility increases with β (or α), so that higher indifference curves correspond to higher levels of utility. The marginal rate of substitution between α and β is given by

$$\frac{d\beta}{d\alpha} = -\frac{E\left[u'_T(\cdot; n)\, g(\varepsilon)\, y_T(n)\right]}{E u'_T(\cdot; n)} \tag{1.4}$$

which clearly depends on n. As shown in Fig.1, given a wage contract $(0, \beta_W)$ (point W), a share tenancy contract (α, β_S) (point S) and a fixed rent contract $(1, \beta_F)$ (point F), tenants might prefer one contract or the other depending on the slope of their indifference curves. In particular tenants with a relatively high marginal rate of substitution prefer the fixed rent contract, while tenants with a relatively flat indifference curve prefer the wage contract.

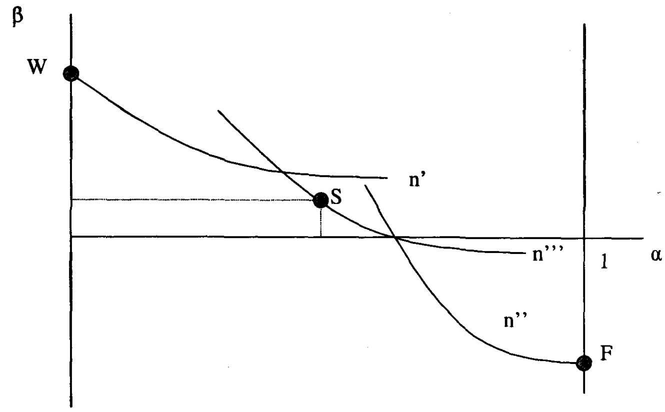

Figure 1: Tenants' indifference curves

In a similar way we can depict landlords' indifference curves when $\alpha \in (0, 1]$ for a given n. The landlord's utility from a given contract depends, in fact, on the expected ability of the pool of tenants choosing that contract. For the time being, however, we only need to represent landlords' indifference curve, and will do this by fixing the level of tenant ability, and not the distribution of tenants conditional on their contract choice. In other words, the only difference between two contracts in the (α, β)-plane is related to the payments and not the abilities of the tenants selected in one contract or the other. As $u_L(\cdot; m)$ is concave and its argument is a negative linear function of α and β, $V_L(\alpha, \beta, n; m)$ is a convex function and the indifference curves are negatively sloped and convex for any given n, as depicted in Fig.2. Given α (or β) landlords' utility decreases with β (or α), so that higher indifference curves correspond to lower levels of utility. The marginal rate of substitution is

$$\frac{d\beta}{d\alpha} = -\frac{E\left[u'_L(\cdot; m)\, g(\varepsilon)\, y_T(n)\right]}{Eu'_L(\cdot; m)} \tag{1.5}$$

which depends on m given n. Even in this case different landlords may prefer different contracts, depending on the slope of their indifference curves. Landlords with flatter indifference curves are more likely to prefer fixed-rent contracts over share tenancy.

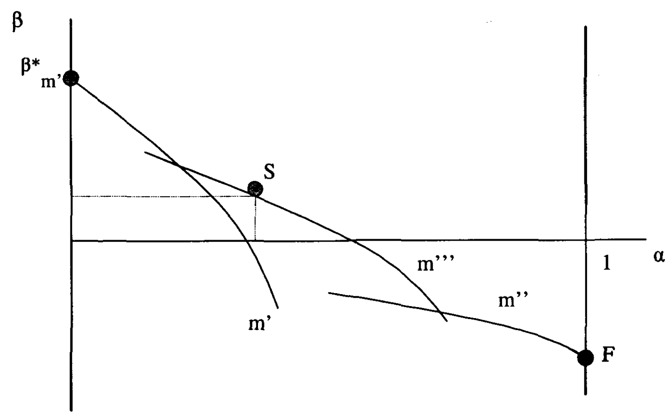

Figure 2: Landlords' indifference curves

Note that the intersection of the landlords' indifference curves with the vertical axis does not identify the wage contract that makes him indifferent with the share tenancy or fixed rent contract, because of the discontinuity of landlords' utilities at $\alpha = 0$. To see this, let $V_L(\alpha', \beta', n; m)$ be the utility level for a landlord m when he rents out the land to a tenant with ability level n under the contract (α', β'). The intersection of this indifference curve with the vertical axis is given by the payment β^* such that $V_L(\alpha', \beta', n; m) = V_L(0, \beta^*, n; m)$, i.e.

$$Eu_L[g(\varepsilon) y_T(n) - \beta^*; m] = Eu_L[(1-\alpha') g(\varepsilon) y_T(n) - \beta'; m]$$

where we simply let the side payment β change, given $\alpha = 0$, so that the landlord is left indifferent with the contract (α', β') keeping everything else constant, in particular $g(\varepsilon) y_T(n)$. Note however that $V_L(0, \beta^*, n; m)$ is not a wage contract as the output depends on the ability level of the tenant n. For a given landlord m there is a unique wage contract such that he is indifferent between $(0, \beta_W)$ and (α', β') and it is implicitly given by

$$Eu_L[g(\varepsilon) y_L(m) - \beta_W; m] = Eu_L[g(\varepsilon) y_T(n) - \beta^*; m]$$

If the tenant n has the same ability level of the landlord, and the output functions for the landlords and tenants are the same, then $y_T(n) = y_L(m)$ and $\beta_W = \beta^*$, but in general this is not true, and it is immediate to see that β_W is an increasing function of β^*.

1.3.2 Existence of Equilibrium: Outline of Proof

The approach taken to prove existence of equilibrium is strictly related to the usual approach adopted in Walrasian economies. First of all, we consider 'markets for contracts' and try to characterize the demand and supply in these markets. To simplify, we find restrictions on tenants and landlords' preferences so that the demand for a specific contract comes from a single interval of tenants, and similarly the supply comes from a single interval of landlords. These restrictions are intended to order tenants and landlords over the unit intervals in terms of their marginal rate of substitution between α (the parameter of the land contract that assigns risk and average income between the tenant and the landlord), and β (the parameter of the contract that transfers income but not risk between the landlord and the tenant). Consequently, we can easily establish continuity of demand and supply (Section 4). Next, we make further restrictions on tenants and landlords' preferences, as well as the set of feasible contract payments to ensure that all markets are active in equilibrium, i.e. that all land contracts are chosen in equilibrium by some landlords and tenants (Section 5). Finally we construct a fixed-point correspondence from the set of feasible contract payments into itself, and show that a fixed-point of this correspondence is an equilibrium for the economy; as the set of contract payments and the correspondence satisfy the assumptions for the application of Kakutani's fixed-point theorem, then we can show that an equilibrium exists (Section 6).

1.4 Demand and Supply Side of the Economy

In this section we characterize the demand and supply of contracts. More specifically, we make assumptions on tenants' and landlords' preferences such that the demand of a specific contract comes from a single interval of tenants, and similarly the supply of such a contract comes from a single interval of landlords. Once this is established, it is possible to express the demand and supply for each contract simply as the cumulative density function over the interval of types who prefer that specific contract, so that continuity of the excess demand for each contract is easily proved. As landlords' income under share tenancy depends on the farming skills of the tenants choosing share tenancy, we first characterize the demand by tenants for the different contracts, and then conditional on tenants' preferences we characterize the supply by landlords.

1.4.1 Tenants' Demand

To ensure that the demand for each contract comes from a single interval of tenants it is enough to assume that

ASSUMPTION 1. $\left.\left(\frac{E\left[u_T'(\cdot;n)g(\varepsilon)y_T(n)\right]}{Eu_T'(\cdot;n)}\right)\right|_{(\alpha,\beta)}$ is a continuous and increasing function of n over all $\alpha \in [0,1]$ and $\beta \in R$.

Assumption 1 requires that tenants with higher index n have a higher marginal rate of substitution between α and β, so that their indifference curves are steeper. To understand the meaning of this assumption in terms of conditions on the primitives we look at the second-order approximation of the expected utility. Using the Arrow-Pratt coefficient of absolute risk aversion, tenants' expected utility can be written as

$$u\left[\alpha y_T(n) + \beta - \frac{1}{2}\alpha^2 y_T^2(n)\,\sigma^2\left(-\frac{u''(\alpha y_T(n)+\beta)}{u'(\alpha y_T(n)+\beta)}\right)\right], \tag{1.6}$$

and taking the total differential with respect to α and β of eq.(6)

$$\frac{d\beta}{d\alpha} = -y_T(n) + \frac{\alpha}{\frac{1}{y_T^2(n)\sigma^2\left(-\frac{u''}{u'}\right)} - \frac{1}{2}\alpha^2\left(\frac{u'''}{u''} - \frac{u''}{u'}\right)} \tag{1.7}$$

Hence, for the approximated utility function, sufficient conditions for the marginal rate of substitution to be increasing in n are:

(i) the risk premium $y_T^2(n)\,\sigma^2\left(-\frac{u''}{u'}\right)$ decreases with n,

(ii) the coefficient of prudence $-\frac{u'''}{u''}$ increases with n.

An increase in n has two effects on the compensative risk premium necessary for a tenant to accept the risk associated with a contract that entails higher risk (higher α). First, as farming ability increases with n, so does the mean income of the tenant, but also his income variance for any given level of exogenous risk (as risk enters in a multiplicative way). The second effect is through the coefficient of absolute risk aversion; by assumption, as n increases, tenants are less risk averse and their compensative risk premium decreases. Condition (i) states that the coefficient of absolute risk aversion decreases with n faster than the increase in $y_T^2(n)$, so that tenants indexed with higher n are more willing to take up risk, as they need a smaller compensation. Condition (ii) is related to the sensitivity to risk of a tenant's choices. As stated in Rothschild and Stiglitz (1971) and Kimball (1990), if marginal utility is convex, then an increase in risk results in an increase in the optimal choice of the control variable. In this specific case, if u''' is positive, higher risk results in the choice of a higher α by the tenant. Condition (ii) requires that the higher n, the more convex is the marginal utility, so that the more sensitive is α to increases in risk. Again, this implies that tenants with higher n are more likely to prefer contracts with higher α, i.e. higher risk.

We start by characterizing the contract demands when there are two generic contracts (α, β) and (α', β') available in the economy, and then consider the case when there are three contracts, and show that the extension is straightforward.

LEMMA 1. Let (α, β) and (α', β') be any two contracts such that $\alpha \leqslant \alpha'$ and $\beta \geqslant \beta'$. If Assumption 1 holds, then

(i) there exists $\widetilde{n} \in [0,1]$ such that $(\alpha,\beta) \succ_n (\alpha',\beta')$ for all $0 \leqslant n < \widetilde{n}$, and $(\alpha,\beta) \prec_n (\alpha',\beta')$ for all $\widetilde{n} < n \leqslant 1$;

(ii) given (α,β), $\widetilde{n}$ is a continuous function of (α',β').

PROOF. See the Appendix

Note that if $\widetilde{n}$ is in the interior of the unit interval, then $\widetilde{n}$ is the 'marginal tenant' or 'switchover' point and identifies the tenant indifferent between (α,β) and (α',β'). If instead all tenants strictly prefer (α,β) to (α',β'), then $\widetilde{n}=1$ and $\widetilde{n}$ may not be indifferent between (α,β) and (α',β'). Similarly, if all tenants prefer (α',β') to (α,β), then $\widetilde{n}=0$. In any case, the contract (α,β) is demanded by the tenants indexed $[0,\widetilde{n})$, while the contract (α',β') is demanded by the tenants indexed $(\widetilde{n},1]$. The second part of the Lemma states that, given any two contracts, the demand for each contract is a continuous function of the contract terms.

Lemma 1, however, concerns pair-wise comparisons of contracts. It is straightforward to show that the demands for contracts come from single intervals of tenants even when there are three contracts available. Intuitively in Fig.1, if a tenant n' prefers the wage contract (point W) to the other two, then any tenant with $n < n'$ prefers the wage contract too; and similarly if a tenant n'' prefers a fixed-rent contract (point F in Fig.1), then any tenant with $n > n''$ prefers the fixed-rent contract too. Suppose now there is a tenant $n''' \in (n', n'')$ who prefers the sharecropping contract (point S) to the other two. Any tenant $n > n'''$ cannot prefer the wage contract to the sharecropping one, since his indifference curve is steeper than the one of n''' at S. Hence, tenants preferring the wage contract must belong to a unique subinterval of tenants' types on the left of n'''; similarly for the tenants preferring the share tenancy contract and the-fixed rent contract.

1.4.2 Landlords' Supply

Similarly for the landlords we assume

ASSUMPTION 2. $\left(\frac{E\left[u_L'(\cdot;m)g(\varepsilon)y_T(n)\right]}{Eu_L'(\cdot;m)}\right)\Big|_{(\alpha,\beta,n)}$ is a continuous and increasing function of m over all $\alpha \in [0,1]$, $\beta \in R$ and $n \in [0,1]$.

Assumption 2 ensures that landlords' indifference curves are steeper for higher m, for a given value of n. By taking a second-order approximation of eq.(3) when $\alpha \in (0,1]$, it is possible to see that this assumption is less restrictive on the primitives of the model than the one for the tenants. The reason is that the marginal rate of substitution depends on m only through the preferences and not through farming ability, since under tenurial contracts the landlord rents out the land and the output depends on the farming ability of the tenant. Hence, in the certainty equivalent approximation of expected utility, a coefficient of absolute risk aversion decreasing in m and a coefficient of prudence increasing in m are sufficient conditions.

As before we characterize the supplies for two generic contracts (α,β) and (α',β'), and then extend to the case when there are three available contracts in the economy.

LEMMA 2. Let (α,β) and (α',β') be any two contracts such that $\alpha \leqslant \alpha'$ and $\beta \geqslant \beta'$. If Assumptions 1 and 2 hold, then

(i) there exists $\widetilde{m} \in [0,1]$ such that $(\alpha,\beta) \prec_m (\alpha',\beta')$ for all $0 \leqslant m < \widetilde{m}$, and $(\alpha,\beta) \succ_m (\alpha',\beta')$ for all $\widetilde{m} < m \leqslant 1$, for a given $\widetilde{n}$;

(ii) given (α, β), $\widetilde{m}$ is a continuous function of (α', β').

PROOF. See the Appendix.

Given the contracts (α, β) and (α', β'), by Lemma 1 we can identify the pool of tenants preferring each contract, and define the utilities of the landlords under the two different contracts. The landlords' choice is therefore between contract (α, β) with tenants $[0, \widetilde{n})$, and contract (α', β') with tenants $(\widetilde{n}, 1]$. The first part of Lemma 2 states the existence of a 'marginal landlord', such that all landlords with steeper indifference curves prefer the contract that entails more risk (lower α), and vice versa for the landlords with flatter indifference curves. Even in this case, if $\widetilde{m}$ belongs to the interior of the unit interval, then $\widetilde{m}$ is the landlord indifferent between the two contracts, while if all landlords prefer one contract over the other, then $\widetilde{m}$ coincides with one of the boundaries of the unit interval.

Suppose now that there are three available contracts. Let m' be a landlord preferring the wage contract $(0, \beta_W)$ to the other two contracts; his indifference curve must lie below the sharecropping and the fixed-rent contract (as shown in Fig.2). Let $\beta^*_{m'}$ be the intercept of the indifference curve associated with the wage contract of such a landlord. For any landlord $m > m'$, the indifference curve associated with the wage contract is steeper and has a lower intercept. The intercept is, in fact, implicitly given by the following equation for the landlord m'

$$Eu_L\left[g(\varepsilon)\, y_L(m') - \beta_W; m'\right] = Eu_L\left[g(\varepsilon)\, y_T(n) - \beta^*_{m'}; m'\right];$$

hence, for any landlord $m > m'$, $y_L(m) > y_L(m')$ and $\beta^*_m < \beta^*_{m'}$. Therefore for $m > m'$, the wage contract is also preferred to the other two contracts. Similarly, let m'' be a landlord preferring the fixed-rent contract most. It follows that any landlord $m < m''$ prefers the fixed-rent contract to the other available contracts. Consider now a landlord $m''' \in (m', m'')$ who prefers the share tenancy contract most. For any landlord $m < m''$, the indifference curves are flatter than that of landlord m' and $\beta^*_m > \beta^*_{m'}$; hence, by construction in Fig.2 it is clear that the wage contract cannot be preferred to the share tenancy contract. Therefore landlords preferring the wage contract must belong to a unique subinterval of landlords' types on the right of m'''. Similarly, for the landlords preferring the share tenancy and fixed-rent contract.

1.5 Restrictions on Contract Payments and Corner Solutions

In this section we find restrictions on the set of contract payments and make additional assumptions on agents' preferences to ensure that all markets are active in equilibrium. This allows us to discard possible corner solutions where one or more contracts are not chosen by any landlord and tenant in equilibrium.

a) Landlords have the option of withdrawing the land from the market. Hence, in equilibrium the rent obtained by the landlord under fixed-rent contract must be non-negative, which implies $\beta_F \leqslant 0$.

b) We assume that the landlord $m = 0$ and the tenant $n = 0$ have infinite risk aversion according to the Arrow-Pratt definition and that the support of $g(\varepsilon)$ is unbounded. This implies that: (i) there is always a strictly positive demand for wage contract by tenants, independently of the share of output that the tenant may retain under share tenancy and of the rent to be paid under fixed-rent contracts, (ii) similarly, there is always a strictly positive supply of fixed-rent contracts by landlords, independently of the share of output under share tenancy and the wage to pay under wage contracts. This ensures that in equilibrium both the fixed-rent contract and the wage contract are chosen by at least some landlords and tenants.

c) Let $\underline{\beta}_F$ be the rent that makes the tenant $n = 1$ indifferent between the wage contract with payment $\beta_W = w$ and the fixed-rent contract (see Fig.3). For any rent greater than $\left|\underline{\beta}_F\right|$, then no tenant demands the fixed-rent contract, as the wage contract dominates it. Since in equilibrium the fixed-rent contract is offered by at least some landlords, $\left|\underline{\beta}_F\right|$ constitutes an upper bound to the payment that landlords may ask from their tenants in equilibrium.

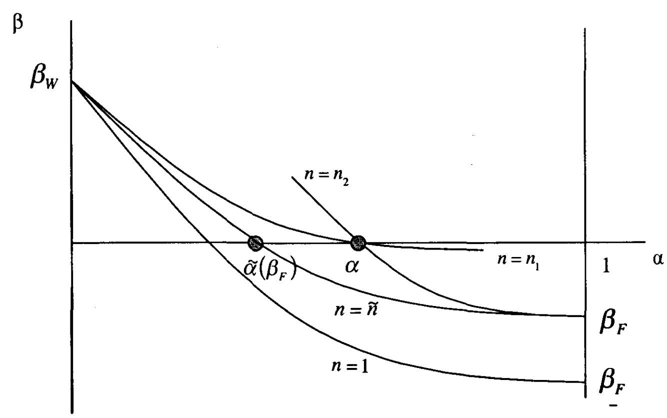

Figure 3: Restrictions on contract payments

d) Let β_F be a generic rent belonging to the interval $\left[\underline{\beta}_F, 0\right]$. Let $\widetilde{n}$ be the tenant indifferent between the wage contract with $\beta_W = w$ and the fixed-rent contract; his indifference curve is as depicted in Fig.3. $\widetilde{n}$ is a decreasing function of β_F since for higher rent payments the tenant indifferent with the wage contract needs to be more able and less risk averse. Let $\widetilde{\alpha}(\beta_F)$ be the share of output that makes the tenant $\widetilde{n}$ indifferent between the wage contract and the share tenancy contract. For any $\alpha < \widetilde{\alpha}(\beta_F)$, then no tenant demands the share tenancy contract. This is easily seen in Fig.3. Since all tenants indexed by $n < \widetilde{n}$ have indifference curves flatter than the ones of tenant $\widetilde{n}$, they prefer the wage contract to the fixed-rent and share tenancy contract; tenants indexed by $n > \widetilde{n}$ have indifference curves steeper than tenant $\widetilde{n}$ and prefer the fixed-rent contract most. Since for any $\alpha < \widetilde{\alpha}(\beta_F)$ no tenant chooses to sharecrop, landlords' expected income under share tenancy is zero. For any landlord share tenancy is therefore dominated by the fixed-rent contract, that offers the landlord full insurance and a fixed income equal to β_F. Any $\alpha < \widetilde{\alpha}(\beta_F)$ can support an equilibrium where share tenancy is not chosen by any tenant or landlord. To avoid this, we restrict the set of feasible shares to be $\alpha > \widetilde{\alpha}(\beta_F)$, so that there is a strictly positive demand of share tenancy contracts by tenants.[14]

In Fig.4 the shaded area represents the set of contract payments that satisfies the restrictions in a), c) and d). We will denote this set by Ω. As β_F increases, $\widetilde{\alpha}(\beta_F)$ increases. The set Ω is not strictly convex. To see this, take any two rent payments β_F^1 and β_F^2, such

[14] Given that $\underline{\beta}_F$ is constructed as the fixed rent that makes tenant $n = 1$ indifferent between the wage contract and the fixed-rent contract, then for any $\beta_F \in \left(\underline{\beta}_F, 0\right)$, the indifferent tenant between the wage contract and the fixed-rent contract $\widetilde{n}$ belongs to the interior of the unit interval. Let $\alpha > \widetilde{\alpha}(\beta_F)$, and n_1 be the tenant indifferent between the wage contract and share tenancy; by construction $n_1 < \widetilde{n}$. Similarly let n_2 be the tenant indifferent between share tenancy and the fixed-rent contract, then $n_2 > \widetilde{n}$. By Lemma 1, the sharecropping contract is demanded by the tenants in the interval (n_1, n_2); since $n_1 < \widetilde{n} < n_2$, then the demand for share tenancy is strictly positive.

that $\beta_F^1 < \beta_F^2$, and let $\alpha_1 = \widetilde{\alpha}\left(\beta_F^1\right)$ and $\alpha_2 = \widetilde{\alpha}\left(\beta_F^2\right)$, where $\widetilde{\alpha}\left(\beta_F^1\right)$ and $\widetilde{\alpha}\left(\beta_F^2\right)$ are as defined in point d), hence $\alpha_1 < \alpha_2$. Let $\beta_F^* = \lambda\beta_F^1 + (1-\lambda)\,\beta_F^2$ with $\lambda \in [0,1]$ be a convex combination of β_F^1 and β_F^2, and $\alpha^* = \lambda\alpha_1 + (1-\lambda)\,\alpha_2$ be the convex combination of α_1 and α_2. The set Ω is convex if $\widetilde{\alpha}\left(\beta_F^*\right) < \alpha^*$ for any $\lambda \in [0,1]$, as shown in Fig.4. But $\widetilde{\alpha}\left(\beta_F^*\right) < \alpha^*$ if and only if $\lambda < \frac{\alpha_2 - \widetilde{\alpha}\left(\beta_F^*\right)}{\alpha_2-\alpha_1}$. Note however that $\widetilde{\alpha}\left(\beta_F^*\right)$ depends on λ as well; in particular for $\lambda = 0$, $\widetilde{\alpha}\left(\beta_F^*\right) = \alpha_1$ and $\frac{\alpha_2 - \widetilde{\alpha}\left(\beta_F^*\right)}{\alpha_2-\alpha_1} = 1$, while for $\lambda = 1$, $\widetilde{\alpha}\left(\beta_F^*\right) = \alpha_2$ and $\frac{\alpha_2 - \widetilde{\alpha}\left(\beta_F^*\right)}{\alpha_2-\alpha_1} = 0$; as λ increases, so does $\widetilde{\alpha}\left(\beta_F^*\right)$, while the function $\frac{\alpha_2 - \widetilde{\alpha}\left(\beta_F^*\right)}{\alpha_2-\alpha_1}$ decreases. Hence, if plotting the functions λ and $\frac{\alpha_2 - \widetilde{\alpha}\left(\beta_F^*\right)}{\alpha_2-\alpha_1}$ over the interval $[0,1]$, the former is a straight increasing line, while the latter is strictly decreasing. For λ sufficiently high, the inequality that ensures strict convexity of Ω is not satisfied.

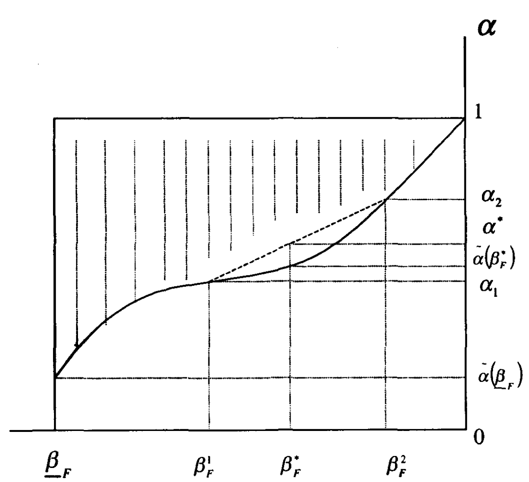

Figure 4: Set of contract payments

1.6 The Existence Theorem

In this section we state and prove the existence theorem for our economy. The approach we take is similar to the one traditionally adopted for a standard Walrasian economy. We consider the excess demand functions for each contract type, construct a fixed-point correspondence from a non-empty, compact, convex set of contract payments into itself, show that the fixed point of this correspondence is an equilibrium in our economy, and verify that the fixed-point correspondence satisfies the conditions for applying Kakutani's fixed-point theorem.

Since there are three 'markets' for land contracts, clearing conditions for two of these markets ensure that the economy is in equilibrium. Consider therefore the markets for share tenancy and fixed-rent contracts. As seen in Section 4, the demands and supplies for contracts come from single intervals of tenants and landlords, and are continuous. Denote by $z_S(\alpha, \beta_F)$ and $z_F(\alpha, \beta_F)$ the excess demand for share tenancy and fixed-rent contract respectively. Given the continuity of the supply and demand functions, these excess demand functions are continuous. Since the wage is determined exogenously by the presence of an urban sector, only the share and the rent are endogenously determined in equilibrium. Denote by $\overline{\Omega}$ the convex hull of Ω. This set is non-empty, compact and convex.

THEOREM 1. If Assumption 1 and 2 hold, then there exists a pair $(\alpha, \beta_F) \in \overline{\Omega}$ such that $z_S(\alpha, \beta_F) = 0$ and $z_F(\alpha, \beta_F) = 0$.

PROOF. We proceed in five steps. In the first three steps, we construct the fixed-point correspondence $f(\alpha, \beta_F)$. We need, in fact, to construct a correspondence for

1. (α, β_F) belonging to the interior of Ω,

2. (α, β_F) belonging to the boundary of Ω with the exclusion of the point $\{\alpha = 1, \beta_F = 0\}$,

3. (α, β_F) belonging to the complement of Ω with respect to its convex hull and the singleton $\{\alpha = 1, \beta_F = 0\}$.

In the fourth step, we show that a fixed point of such a correspondence is an equilibrium. Finally, in the fifth step we verify that the correspondence satisfies the conditions for the application of Kakutani's fixed point theorem, establishing the existence of a fixed point for the correspondence. The only point of departure from the standard approach may seem to be in that the landlords' supply for each contract depends on the tenants' choices. Given that in section 4 we have shown continuity of landlords' supply conditional on the *distributions* of tenants choosing the different contracts, it is enough to impose that in equilibrium excess demands are zero to have that all markets clear and landlords and tenants choices are compatible with each other.

Step 1: Construction of the fixed-point correspondence for $(\alpha, \beta_F) \in$ Interior Ω.

For any (α, β_F) in the interior of the set Ω (the shaded area in Fig.5) we define

$$f(\alpha, \beta_F) = \left\{ (\alpha', \beta'_F) \in \overline{\Omega} : (\alpha', \beta'_F) = \underset{(\alpha'', \beta''_F)}{\arg\max}\ z_S(\alpha, \beta_F) \cdot (1 - \alpha'') + z_F(\alpha, \beta_F) \cdot |\beta''_F| \right\}. \tag{1.8}$$

Note that $z_S(\alpha, \beta_F) \cdot (1 - \alpha'') + z_F(\alpha, \beta_F) \cdot |\beta''_F|$ represents the value of excess demand where $(1 - \alpha'')$ (i.e. the share that goes to the landlord under share tenancy) and $|\beta''_F|$ (i.e. the rent paid to the landlord under fixed-rent contracts) represent the 'prices' that the tenant pays under each contract. Therefore, given (α, β_F), this correspondence assigns (α', β'_F) that maximize the value of excess demand. To better understand, suppose that at (α, β_F) the economy has an excess demand of fixed-rent contracts and an excess supply of share tenancy, i.e. $z_F(\alpha, \beta_F) > 0$ and $z_S(\alpha, \beta_F) < 0$. The correspondence then assigns $\beta'_F = \underline{\beta}_F$ and $\alpha' = 1$, i.e. it assigns the highest possible rent (given that the market had excess demand of fixed-rent contracts) and the highest possible share for the tenant (given that there was excess supply of share tenancy contracts). Similarly, if $z_F(\alpha, \beta_F) > 0$ and $z_S(\alpha, \beta_F) > 0$, then the correspondence assigns $\beta'_F = \underline{\beta}_F$ and $\alpha' = \tilde{\alpha}\left(\underline{\beta}_F\right)$. It is easy to check that even when $z_F(\alpha, \beta_F) < 0$ and $z_S(\alpha, \beta_F) \lesseqgtr 0$, the correspondence assigns a vector of 'prices' $\left(\alpha', \beta'_F\right)$ which is on the boundary of $\overline{\Omega}$.

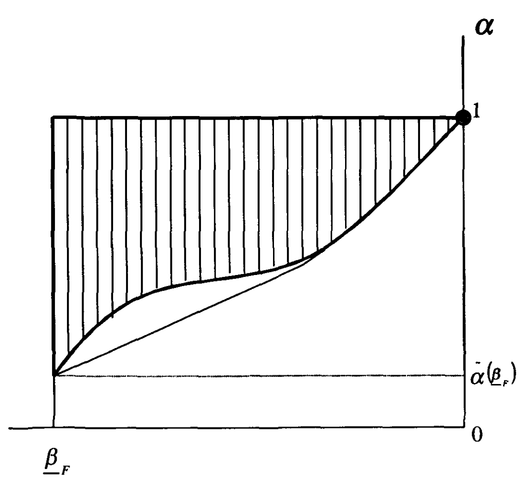

Figure 5

Step 2: Construction of the fixed-point correspondence for

$(\alpha, \beta_F) \in$ *Boundary* $\Omega / \{\alpha = 1, \beta_F = 0\}$.

For any (α, β_F) belonging to the boundary of Ω (the darker line in Fig.5) with the exclusion of the point $\{\alpha = 1, \beta_F = 0\}$ we define the following correspondence

$$f(\alpha, \beta_F) = \{(\alpha', \beta'_F) \in \overline{\Omega} : |\beta_F| \cdot |\beta'_F| + (1-\alpha) \cdot (1-\alpha') = 0\}. \tag{1.9}$$

Note that for any (α, β_F), the function $|\beta_F| \cdot |\beta'_F| + (1-\alpha) \cdot (1-\alpha')$ is equal to zero only for $\beta'_F = 0$ and $\alpha' = 1$. Hence no (α, β_F) on the boundary of Ω with the exclusion of the singleton $\{\alpha = 1, \beta_F = 0\}$ can be a fixed point of the correspondence.

Step 3: Construction of the fixed-point correspondence for $(\alpha, \beta_F) \in \overline{\Omega}/\Omega \cup \{\alpha = 1, \beta_F = 0\}$.

Finally, the last correspondence is defined over the complement of the set Ω with respect to its convex hull and the singleton $\{\alpha = 1, \beta_F = 0\}$. For any (α, β_F) belonging to this set we define the following correspondence

$$f(\alpha, \beta_F) = \left\{(\alpha', \beta'_F) \in \overline{\Omega} : \left|\beta_F - \underline{\beta}_F\right| \cdot \left|\beta'_F - \underline{\beta}_F\right| + (1-\alpha) \cdot (1-\alpha') = 0\right\}. \tag{1.10}$$

Note that for any (α, β_F), the function $\left|\beta_F - \underline{\beta}_F\right| \cdot \left|\beta'_F - \underline{\beta}_F\right| + (1-\alpha) \cdot (1-\alpha')$ is equal to zero only if $\beta'_F = \underline{\beta}_F$ and $\alpha' = 1$; therefore, as in step 2, no (α, β_F) over which this correspondence is defined can be a fixed point.

Step 4: A fixed point of f is an equilibrium where all markets are active

Suppose (α^*, β^*_F) is a fixed point of f. Then, as pointed out in step 2 and 3, (α^*, β^*_F) must belong to the interior of Ω. If $z_S(\alpha^*, \beta^*_F) \neq 0$ and/or $z_F(\alpha^*, \beta^*_F) \neq 0$, then as seen in step 1 $f(\alpha^*, \beta^*_F) \subset$ *Boundary* $\overline{\Omega}$, which contradicts the fact that (α^*, β^*_F) is a fixed point of f and that $(\alpha^*, \beta^*_F) \in$ *Interior* Ω. Hence, it must be that $z_S(\alpha^*, \beta^*_F) = 0$ and $z_F(\alpha^*, \beta^*_F) = 0$.

Step 5: Kakutani's fixed point theorem

To apply Kakutani's fixed point theorem, we need to ensure that: a) $\overline{\Omega}$ is nonempty, compact and convex; b) f is convex valued and upper hemicontinuous. It is immediate to see that a) holds. To prove upper hemicontinuity we need to show that if taking two sequences $(\alpha_n, \beta_{Fn}) \to (\alpha, \beta_F)$ and $(\alpha'_n, \beta'_{Fn}) \to (\alpha', \beta'_F)$ with $(\alpha'_n, \beta'_{Fn}) \in f(\alpha_n, \beta_{Fn})$, then $(\alpha', \beta'_F) \in f(\alpha, \beta_F)$. We distinguish the following cases:

Case 1: $(\alpha, \beta_F) \in$ *Interior* Ω. Then (α_n, β_{Fn}) belongs to the interior of Ω for n large enough, and $z_S(\alpha_n, \beta_{Fn}) \cdot (1 - \alpha'_n) + z_F(\alpha_n, \beta_{Fn}) \cdot |\beta'_{Fn}| \geqslant z_S(\alpha_n, \beta_{Fn}) \cdot (1 - \alpha'') + z_F(\alpha_n, \beta_{Fn}) \cdot |\beta''_F|$ for any (α'', β''_F) by definition of f in step1. By continuity of z we get $z_S(\alpha, \beta_F) \cdot (1 - \alpha') + z_F(\alpha, \beta) \cdot |\beta'_F| \geqslant z_S(\alpha, \beta_F) \cdot (1 - \alpha'') + z_F(\alpha, \beta_F) \cdot |\beta''_F|$ for any (α'', β''_F) which implies $(\alpha', \beta'_F) \in f(\alpha, \beta_F)$.

Case 2: $(\alpha, \beta_F) \in$ *Boundary* $\Omega / \{\alpha = 1, \beta_F = 0\}$. There are two different situations. If (α_n, β_{Fn}) belongs to *Boundary* $\Omega / \{\alpha = 1, \beta_F = 0\}$, then $(\alpha'_n, \beta'_{Fn}) \in f(\alpha_n, \beta_{Fn})$ is such that $\alpha'_n = 1$ and $\beta'_{Fn} = 0$ by definition of f in step 2. But this implies that $\alpha' = 1$ and $\beta'_F = 0$, and that $|\beta_F| \cdot |\beta'_F| + (1 - \alpha) \cdot (1 - \alpha') = 0$, hence $(\alpha', \beta'_F) \in f(\alpha, \beta_F)$ by definition of f in step 2. If instead (α_n, β_{Fn}) belongs to *Interior* Ω but it is close enough to the boundary, then by definition of f in step 1, f will assign $\alpha'_n = 1$ if α_n is close to the lower boundary of Ω, and $\beta'_{Fn} = 0$ if β_{Fn} is close to $\underline{\beta}_F$. Hence, again $|\beta_F| \cdot |\beta'_F| + (1 - \alpha) \cdot (1 - \alpha') = 0$ and $(\alpha', \beta'_F) \in f(\alpha, \beta_F)$. This shows that f is continuous across the boundaries of Ω.

Case 3: $(\alpha, \beta_F) \in \overline{\Omega}/\Omega \cup \{\alpha = 1, \beta_F = 0\}$. For n large enough (α_n, β_{Fn}) belongs to the interior of the set $\overline{\Omega}/\Omega$, and by definition of f in step 3, $\alpha'_n = 1$ and $\beta'_{Fn} = \underline{\beta}_F$. Hence $\alpha' = 1$ and $\beta'_F = \underline{\beta}_F$ and $\left|\beta_F - \underline{\beta}_F\right| \cdot \left|\beta'_F - \underline{\beta}_F\right| + (1 - \alpha) \cdot (1 - \alpha') = 0$, so that $(\alpha', \beta'_F) \in f(\alpha, \beta_F)$.

To prove that f is convex-valued is enough to notice that f is a level set of a linear function defined on the convex set $\overline{\Omega}$ and it is convex (see Mas-Colell, et al., 1995). We can, therefore, conclude that there exists a $(\alpha^*, \beta_F^*) \in \overline{\Omega}$ such that $(\alpha^*, \beta_F^*) = f(\alpha^*, \beta_F^*)$.

1.7 Comparative Statics: the Effect of Risk on Contract Choice

One of the major pitfalls of agency theory, when applied to the study of agrarian contracts, is that it leads to the prediction that the relative frequency of share tenancy with respect to fixed rent contracts should increase when farming risk increases. As mentioned earlier in this chapter, empirical evidence is sometimes at odds with this conclusion. In this section we show that the theoretical framework proposed is able, under certain conditions, to predict a negative relation between farming risk and frequency of share tenancy relative to fixed rent contracts.

Note first that, in the model proposed, the only source of uncertainty is related to output, and is purely exogenous. No individual action may affect the degree of output uncertainty represented by the random variable ε. This is absolutely compatible with the traditional models of moral hazard, so that the respective predictions can be easily compared. Furthermore, in the following we always refer to higher uncertainty in farming activity as a situation where the variance of the random shock on output, i.e. σ_ε^2, is higher. This implies that the results of the comparative statics can directly be tested empirically, after obtaining a measure of exogenous output variance.

In general, in the model proposed the effect of exogenous risk on the equilibrium frequency of contracts depends in a complex way on the individuals' preferences towards risk, their ability and the initial level of risk. In the following, we study a parameterized version of the model and analyze the relation between risk and contract choice under different situations. Even though it is not possible to obtain precise restrictions on the sets of parameters that generate a positive or negative relation between risk and relative frequency of share tenancy over fixed rent contracts, the numerical examples help obtain an idea of the different forces underlying the model and of the cases in which a negative relation is more likely to occur.

The parameterized model we use for the simulation assumes the following:

(a) the production function is Cobb-Douglas in labor, and additive in risk and ability;

(b) the utilities display constant absolute risk aversion;

(c) agents' types are distributed uniformly over the intervals $[0,1]$ and $[0,\overline{n}]$.

More specifically we assume that the production function takes the following form

$$Y = \begin{cases} \ell^c T + b_L m + g(\varepsilon) & \text{if wage contract} \\ \\ \ell^c T + b_T \frac{n}{\overline{n}} + g(\varepsilon) & \text{if tenurial contract} \end{cases} \tag{1.11}$$

where b_L and b_T represents the productivity of landlords and tenants' farming skills respectively. Note furthermore that under tenurial contracts, it is the relative ability of the tenants that matters and not the absolute level, so that the results do not depend on the absolute indexing of the tenants over the interval $[0, \overline{n}]$. The optimal choice of labor is

$$\ell = \begin{cases} \left(\frac{cT}{\beta_W}\right)^{\frac{1}{1-c}} & \text{if wage contract} \\ \\ \left(\frac{\alpha c T}{\beta_W}\right)^{\frac{1}{1-c}} & \text{if tenurial contract.} \end{cases} \tag{1.12}$$

The utility functions are of the form $u = -\frac{1}{\gamma}\exp(-\gamma I)$, where I is the income obtained by the agents under a specific land contract, and γ is the coefficient of absolute risk aversion. Such a coefficient is a function of the agents' type, and we assume that it takes the form

$$\gamma = \begin{cases} \gamma_T\left(\frac{\overline{n}-n}{\overline{n}}\right) & \text{for a tenant } n \\ \\ \gamma_L(1-m) & \text{for a landlord } m. \end{cases} \tag{1.13}$$

This functional form satisfies the Assumption 1 in section 3, i.e. agents with a higher index are less risk averse. γ_T and γ_L are parameters that regulate the average risk aversion of the pool of tenants and landlords. Assuming that landlords and tenants are uniformly distributed over the intervals $[0, 1]$ and $[0, \overline{n}]$, then the risk aversion of the median tenant is $\frac{\gamma_T}{2}$, while for the median landlord is $\frac{\gamma_L}{2}$.

Note that we depart from the model described in the previous sections in one relevant dimension. Labor choice is endogenous, in the sense that the tenant under a share tenancy or fixed rent contract, and the landlord under a wage contract respectively choose the quantity of labor to use. Though we assume implicitly that monitoring labor under a wage contract is costless, so that no shirking may arise from the tenant side, the traditional result of

Marshallian inefficiency of share tenancy holds since the tenant chooses labor by equating the full marginal cost of labor to his share of the marginal output. Since we now allow landlords to hire multiple tenants under the wage contracts, we need to assume that $\overline{n} > 1$, i.e. the support of tenants' type is greater than the one for the landlords. This ensures that there is no binding constraint on the availability of wage workers, even if landlords decide to hire more than one laborer under wage contracts.

Let $\widetilde{n}_1$ be the tenant indifferent between the wage and the sharecropping contract, and $\widetilde{n}_2$ be the tenant indifferent between the share tenancy and the fixed rent contracts; similarly, let $\widetilde{m}_1$ and $\widetilde{m}_2$ be the respective marginal landlords. These marginal agents are identified by equating the utilities out of the respective contracts they are indifferent with. These conditions give a system of four equations in six unknowns, i.e. the four marginal agents plus the contract payments α and β_F. To close the system and get the solution we impose that in equilibrium the demand of fixed rent contracts must equal the supply, i.e. $\overline{n} - \widetilde{n}_2 = \widetilde{m}_2$, and similarly for the demand and supply of share tenancy, i.e. $\widetilde{n}_2 - \widetilde{n}_1 = \widetilde{m}_2 - \widetilde{m}_1$.

For the numerical exercise, we need to parameterize the model assigning values to β_W and c; since in perfect competition the labor share of output is equal to the real wage, we set both of them equal to 0.8.[15] The range of values for the exogenous risk over which we simulate the changes in the equilibrium ratio of sharecropping over fixed rent contracts is $[0.5, 1.5]$. This range is consistent in equilibrium with a coefficient of variation (i.e. variance of the output over average output) ranging from 20 to 70 percent which is what found by

[15] This value is close to the empirical estimate obtained in Chapter 2.

Walker and Ryan (1990) in India.

In Fig.6 we show the variation in the equilibrium proportion of sharecropping over fixed rent contracts when the average coefficient of absolute risk aversion for the landlords is equal to 1 and the average coefficient for the tenants ranges from 0.5 to 3. The average ability of the two groups is fixed and equal to 1. Note that the relative frequency of share tenancy to fixed rent contracts depends negatively on risk for low values of tenants' average risk aversion, while it has a non-monotonic relation for higher values. This result, however, is not robust to changes in the benchmark level of landlords' average risk aversion. Fig.7 shows the simulation of the model when the landlords' average coefficient of risk aversion is raised to 2. The non-monotonic relation with risk disappears and the contracts' ratio always decreases.

To clarify these results, let us look at the separate effects that a change in risk has on the demand and supply for contracts. An increase in farming risk causes the tenants' indifference curves to become flatter, so that the marginal tenants correspond now to higher indices. In other words, given the higher level of output risk, the marginal tenants must have lower risk aversion and higher ability, as the contract payments have not been adjusted to compensate for the higher risk. A variation in the marginal tenants implies a variation in the demand for the different contracts, and in particular an increase in risk shifts tenants preferences towards less risky contracts, i.e. from the fixed rent contract to the sharecropping one, and from the sharecropping to the wage contract. Clearly, this effect depends on the average coefficient of risk aversion; if tenants are on average highly risk averse, then the relative demands of the different contracts are more sensitive to a change in risk. On the other side, landlords' supply of contracts is affected by a variation in risk in two ways. First, there is a *direct* effect similar to the one analyzed for the tenants, under the assumption that landlords are risk averse. In this case, an increase in risk shifts landlords' preferences from wage contract to share tenancy, and from share tenancy to fixed rent contracts. A second *indirect* effect is, instead, due to the change in the pool of tenants choosing sharecropping, which affects the landlords' mean income and risk associated with share tenancy. In general higher risk selects more able tenants into sharecropping, so that the expected output under share tenancy increases. But nothing can be said about the induced change in the variance of the pool of tenants.

It is therefore not possible to sign the overall effect of an increase in risk on the equilibrium distribution of contracts, as it depends on the relative elasticities of the agents' preferences towards risk. In presence of this indirect effect, matters become even more complex. It is still possible, however, to give an intuitive explanation for the results shown in Fig.6 and 7.

First, consider the case when the landlords' average coefficient of risk aversion is relatively small ($\gamma_L = 1$). When risk is low, an increase in risk induces a substantial shift in the marginal tenants (since the percentage increase in risk is quite high), so that the average level of tenants' skills under share tenancy increases significantly. If the tenants' average coefficient of risk aversion is relatively high, the direct effect of risk on tenants' preferences is amplified, while it does not have the same strength on the supply side given that γ_L is low. The new equilibrium is therefore the results of two main forces: on one side tenants move from fixed rent contracts to share tenancy contracts, on the other side landlords find share tenancy more attractive because of the better selection of tenants. In this situation, therefore, an increase in risk is more likely to cause an increase in the relative frequency of share tenancy over fixed rent contracts. This case corresponds to the upper-left part of Fig.6. For lower levels of tenants' average risk aversion, the effect of risk on tenants' preferences is milder, and so is the indirect effect on output under share tenancy. This explains the flatter curves at the bottom-left part of the diagram, where apparently a change in risk has very little effect on the contract ratio. If we move further to the right of the diagram, and consider higher levels of risk, we are attenuating the effect of an increase in risk on tenants' preferences (since the percentage increase is lower), and therefore the strength of the output effect. This causes the share of sharecropping contracts over fixed rent ones to remain unaltered (if tenants risk aversion is low - bottom-right corner of the diagram), or to even decrease (upper-right corner).

In this scenario an increase in landlords' average coefficient of risk aversion is reinforcing the direct effect of risk on landlords' preferences, for which there is a shift from share tenancy towards fixed rent contracts. Therefore, an increase in γ_L makes it more likely that in equilibrium an increase in risk causes the relative frequency of share tenancy to decrease with respect to fixed rent contracts.

Finally, in Fig.8 we show the equilibrium proportion of share tenancy over fixed rent contracts when the coefficients of average risk aversion are both set equal to 1, and the landlords' average ability level is 1. For a low level of risk, the output effect under share tenancy becomes more and more important as the average tenants' ability increases, so that a positive relation of the contract ratio with risk is more likely to occur (upper-left corner of the picture). In all other cases, this effect is milder so that the curves have either a negative slope or are flat.

These results show that even in a model where share tenancy is chosen only for its risk-sharing feature, its relative frequency may actually decrease with risk. Furthermore, even in the presence of substantial risk aversion on the tenants' side, and even in the case when tenants are more risk averse than landlords, this negative relation may still hold.

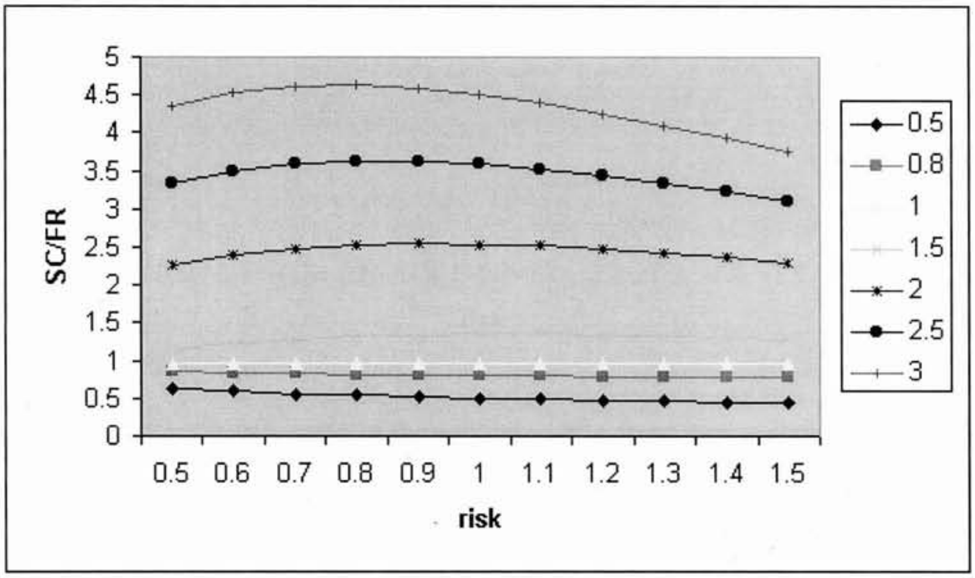

Figure 6: Equilibrium ratio of sharecropping over fixed-rent contracts ($\gamma_L = 1$)

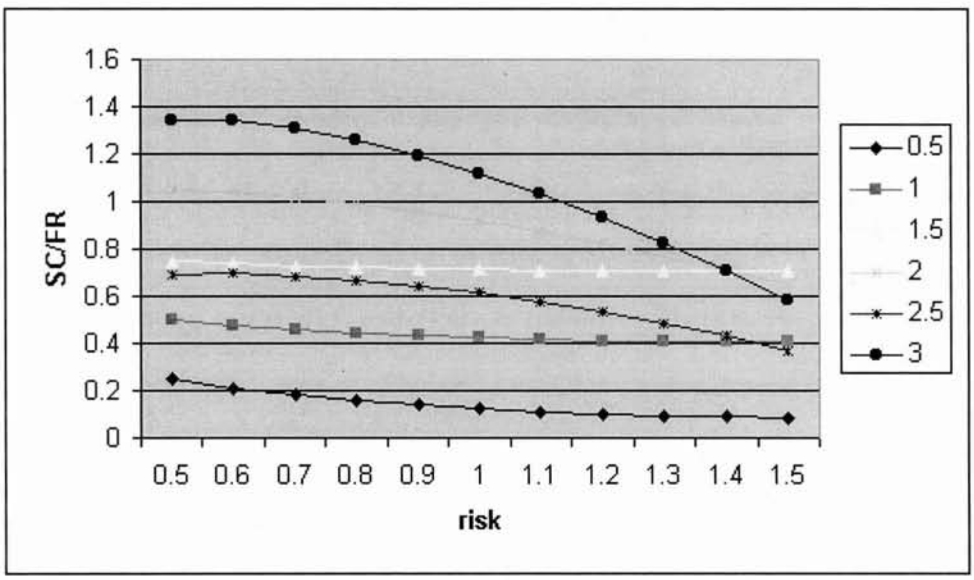

Figure 7: Equilibrium ratio of sharecropping over fixed rent contracts ($\gamma_L = 2$)

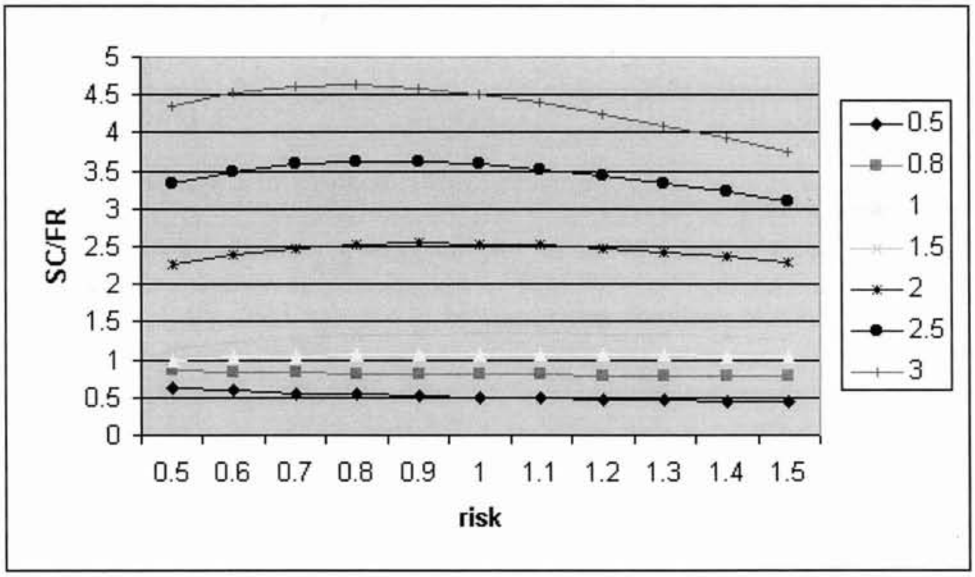

Figure 8: Equilibrium ratio of sharecropping over fixed rent contracts ($b_L = 1$)

1.8 Conclusion

In this chapter we propose an original theoretical framework to analyze the choice of agrarian contracts in risky environments. Differently from the canonical agency model, typically applied in the literature, we adopt a general equilibrium framework where landlords as well as tenants choose the contract they prefer considering as given the contract payments. Market forces push the payments so as to remove excess demands in equilibrium. We show that this model can predict, under certain conditions, that the ratio of share tenancy contracts over fixed rent contracts observed in equilibrium may depend negatively on risk, even in presence of substantial risk aversion on the tenants' side.

Appendix: Proofs

Lemma 1. (Proof)

(i) A rigorous proof is in Westhoff (1974). Intuitively, given Assumption 2, it is immediate to see that the indifference curves of any two tenants intersect only once. Let $\widetilde{n}$ be such that $(\alpha, \beta) \sim_{\widetilde{n}} (\alpha', \beta')$. Take any $n < \widetilde{n}$; by assumption the slope of n's indifference curve passing through (α, β) is lower than the slope of the indifference curve of $\widetilde{n}$ (see Fig.A1). As two indifference curves intersect only once, then (α', β') must be in the worse than set of tenant n, so that $(\alpha, \beta) \succ_n (\alpha', \beta')$. Similarly for $n > \widetilde{n}$.

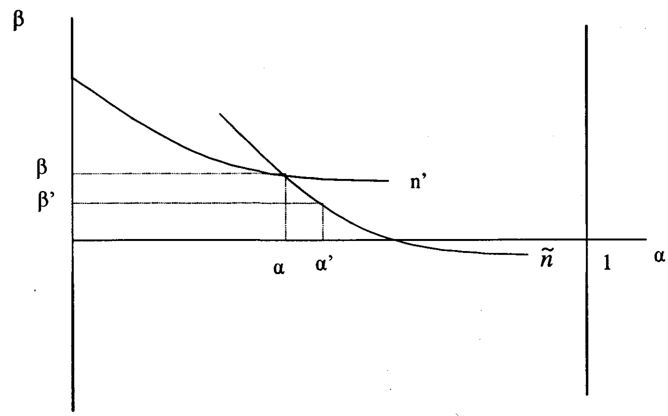

Figure A1

(ii) Let $\widetilde{n}(\alpha', \beta')$ be the tenant such that $(\alpha, \beta) \succ_n (\alpha', \beta')$ $\forall n \in [0, \widetilde{n}(\alpha', \beta'))$, and $(\alpha, \beta) \prec_n (\alpha', \beta')$ $\forall n \in (\widetilde{n}(\alpha', \beta'), 1]$. To prove that $\widetilde{n}(\alpha', \beta')$ is continuous in (α', β') for given (α, β), we need to show that $\forall \epsilon > 0$, $\exists\ \delta > 0$ such that if $|\alpha'_0 - \alpha'_1| < \delta$ and

$\left|\beta_0' - \beta_1'\right| < \delta$, then $\left|\widetilde{n}\left(\alpha_0', \beta_0'\right) - \widetilde{n}\left(\alpha_1', \beta_1'\right)\right| < \epsilon$.

Let $\widetilde{n}\left(\alpha_0', \beta_0'\right)$ as defined above when comparing (α, β) and $\left(\alpha_0', \beta_0'\right)$, then the following is true

$$(\alpha, \beta) \succ_{\widetilde{n}\left(\alpha_0', \beta_0'\right)-\epsilon} \left(\alpha_0', \beta_0'\right) \text{ and}$$
$$(\alpha, \beta) \prec_{\widetilde{n}\left(\alpha_0', \beta_0'\right)+\epsilon} \left(\alpha_0', \beta_0'\right), \forall \epsilon > 0.$$

Hence for the tenant $\widetilde{n}\left(\alpha_0', \beta_0'\right) - \epsilon$ the contract (α, β) lies above the indifference curve, while the contract $\left(\alpha_0', \beta_0'\right)$ lies below the indifference curve. The opposite is true for $\widetilde{n}\left(\alpha_0', \beta_0'\right) + \epsilon$, as shown in Fig.A2. Construct the largest possible circle around $\left(\alpha_0', \beta_0'\right)$ that intersects each indifference curve at most once, and let the radius be $\delta > 0$. Take any $\left(\alpha_1', \beta_1'\right)$ within the circle, and let $\widetilde{n}\left(\alpha_1', \beta_1'\right)$ be the marginal tenant when comparing (α, β) and $\left(\alpha_1', \beta_1'\right)$. By construction $(\alpha, \beta) \succ_{\widetilde{n}\left(\alpha_0', \beta_0'\right)-\epsilon} \left(\alpha_1', \beta_1'\right)$ and $(\alpha, \beta) \prec_{\widetilde{n}\left(\alpha_0', \beta_0'\right)+\epsilon} \left(\alpha_1', \beta_1'\right)$. Then $\widetilde{n}\left(\alpha_0', \beta_0'\right) - \epsilon < \widetilde{n}\left(\alpha_1', \beta_1'\right) < \widetilde{n}\left(\alpha_0', \beta_0'\right) + \epsilon$. Hence $\left|\widetilde{n}\left(\alpha_0', \beta_0'\right) - \widetilde{n}\left(\alpha_1', \beta_1'\right)\right| < \epsilon$.

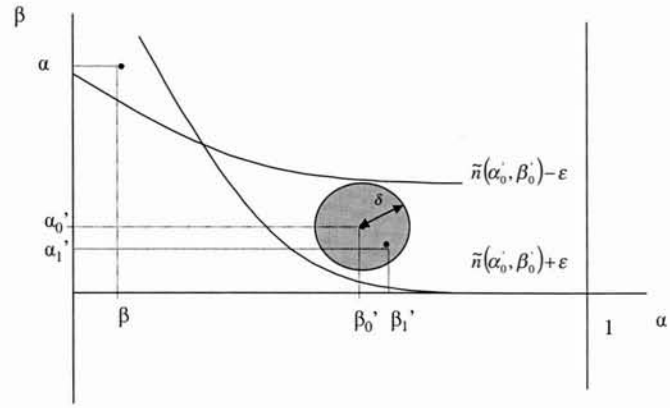

Figure A2

Lemma 2. (Proof)

(i) Similarly to part (i) in Lemma 1, it is possible to show that there exists a $\widetilde{m}$ such that, for all landlords $m < \widetilde{m}$, $(\alpha, \beta) \prec_m (\alpha', \beta')$ for any given n, and vice versa for $m > \widetilde{m}$. Indicate this 'marginal landlord' by $\widetilde{m}(n)$, to make clear that the switchover point depends on the specific level of tenant's ability n. We need to show, however, that such a marginal landlord exists conditional on the tenants' preferences over (α, β) and (α', β'), and therefore conditional on $\widetilde{n}$. Let $V(\alpha, \beta, n; m)$ be the expected utility of landlord m under contract (α, β) conditional on the specific level of tenant's ability n, as defined in eq.(3). Given the two contracts (α, β) and (α', β'), by Lemma 1 we know that the pool of tenants $[0, \widetilde{n})$ prefers (α, β), while the tenants $(\widetilde{n}, 1]$ prefer contract (α', β'). The expected utility of landlord m unconditional on n, but conditional on tenant's preferences, is given by the expected utility over the ability level of the tenants choosing the contract (α, β) and it is therefore given by

$$\int_0^{\widetilde{n}} V(\alpha, \beta, n; m) \frac{1}{\widetilde{n}} dn.$$

Similarly the expected utility from contract (α', β') is given by

$$\int_{\widetilde{n}}^1 V(\alpha', \beta', n; m) \frac{1}{1-\widetilde{n}} dn.$$

We need to show that there exists an $\widetilde{m}$ such that

$$\begin{aligned} \int_0^{\widetilde{n}} V(\alpha, \beta, n; m) \frac{1}{\widetilde{n}} dn &< \int_{\widetilde{n}}^1 V(\alpha', \beta', n; m) \frac{1}{1-\widetilde{n}} dn \text{ if } m < \widetilde{m} \\ \text{and } \int_0^{\widetilde{n}} V(\alpha, \beta, n; m) \frac{1}{\widetilde{n}} dn &> \int_{\widetilde{n}}^1 V(\alpha', \beta', n; m) \frac{1}{1-\widetilde{n}} dn \text{ if } m > \widetilde{m}. \end{aligned}$$

We prove this by showing that $\int_0^{\widetilde{n}} V(\alpha, \beta, n; m) \frac{1}{\widetilde{n}} dn - \int_{\widetilde{n}}^1 V(\alpha', \beta', n; m) \frac{1}{1-\widetilde{n}} dn$ is increasing in m.

First, scale each landlord's utility so that $V(\alpha, \beta, n; m) = c$ for all m, where c is a constant. This implies that $\int_0^{\widetilde{n}} V(\alpha, \beta, n; m) \frac{1}{\widetilde{n}} dn = c$. Note that $V(\alpha, \beta, n; m) - V(\alpha', \beta', n; m)$ is an increasing function of m. This follows from the fact that less risk averse landlords (higher m) require lower compensation to accept the higher risk associated with the contract (α, β). Hence,

$$\begin{aligned} \frac{d}{dm}\left[V(\alpha, \beta, n; m) - V(\alpha', \beta', n; m)\right] &= -\frac{d}{dm} V(\alpha', \beta', n; m) > 0 \\ &\Rightarrow \frac{d}{dm} V(\alpha', \beta', n; m) < 0. \end{aligned}$$

and

$$\frac{d}{dm}\left[\int_0^{\tilde{n}} V\left(\alpha,\beta,n;m\right)\frac{1}{\tilde{n}}dn-\int_{\tilde{n}}^1 V\left(\alpha',\beta',n;m\right)\frac{1}{1-\tilde{n}}dn\right]=-\int_{\tilde{n}}^1 \frac{d}{dm}V\left(\alpha',\beta',n;m\right)\frac{1}{1-\tilde{n}}dn>0.$$

(ii) Continuity of the switchover landlord can be established following the same line of proof as for the marginal tenant.

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Chapter 2

Land Contracts as a Two-Side Occupational Choice: New Evidence of Risk-Sharing in India

2.1 Introduction

The canonical Principal-Agent model, applied to the analysis of land contracts, predicts that higher farming risk is associated with higher frequency of share tenancy over fixed rent contracts. Empirical evidence is somewhat mixed. A few studies have found a negative empirical relation between crop risk and the incidence of sharecropping (Rao, 1971; Allen and Lueck, 1999), while in others share tenancy seems indeed to be associated with riskier crops (Ackerberg and Botticini, 2000).

A possible explanation for these findings is that most of the empirical work is based on the assumption that crop choice is exogenous, in the sense that crop choice is entirely driven by the plot characteristics. Therefore, the riskiness of the plot can be proxied fairly well by the riskiness of the crop cultivated. However, if the crop can be chosen by the cultivator of the plot, then there may be incentives for the fixed rent tenants to choose riskier crops than share tenants. Since these incentives cannot be ruled out even within a Principal-Agent framework, the empirical observation of fixed rent contracts associated more frequently with riskier crops does not imply a rejection of the agency theory models.[1] Instead, in order to test for the Principal-Agent framework, empirical work should explore the relation between contract choice and farming risk, controlling for crop choice incentives.

More generally, however, the Principal-Agent framework may be subject to criticism when used to study certain agrarian economies, due to the sometimes unrealistic assumption of an exploitative landlord-peasant relationship. In the previous chapter we showed how in a competitive framework, where landlords and tenants decide the contract to sign considering as given the contract payments, both economic agents can gain a surplus, and the predicted relation between risk and contract choice depends on the primitives of the model.

The purpose of the present chapter is to shed light on the empirical determinants of contract choice and the risk-sharing role of share tenancy in an agrarian economy. Our attention is focused on the Indian villages that participated in the survey conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) between 1975 and 1984. In this area weather uncertainty and soil characteristics make agricultural activity highly risky compared to the rest of the country, so that there is significant scope for risk-

[1] Basu (1992) finds that a Principal-Agent model with limited liability generates a moral hazard problem in risk-taking behavior by the tenant; hence, tenants under fixed rent contracts engage in riskier farming techniques than share tenants.

sharing through contract choice. Our empirical strategy is first to test the predictions of the principal-agent framework allowing crop choice to be endogenous, and second to analyze the empirical relation between risk and contract choice using the theoretical approach formalized in Chapter 1.

To test the principal-agent theory, we derive different sets of predictions on the relation between contract choice and plot risk on one hand, and contract choice and crop risk on the other, under both assumptions that crop choice is exogenous and endogenous. This involves obtaining two different measures of output risk for any given plot, one related to the exogenous risk of farming a specific plot regardless of the crop planted, and the other related to the crop uncertainty. We find that in the villages studied share tenancy is more frequent than fixed rent contracts when exogenous plot uncertainty is lower, whether crop choice is considered exogenous or not. Thus the predictions of the Principal-Agent framework are unambiguously rejected.

Next, we estimate a parameterized version of the model described in the previous chapter, that captures the specific features of the Indian villages under study. The structural form proposed separately models the probabilities of landlords to offer and tenants to accept the different contracts, and it embeds both the risk-sharing features and the effort incentive problems related to the specific contracts. Hence, the structural estimates of the model allow us to: a) identify the risk-sharing mechanism after controlling for the effect of moral hazard on the individual choices, and b) disentangle the effect of output risk on the preferences of landlords and tenants. In this way it is possible to understand whether share tenancy is more frequent in less risky environments because risk-sharing is irrelevant or because such relation is the resulting 'net effect' of risk on the contract distribution that combines the effects on both sides of the land contract market.

We find that both landlords and tenants are risk averse so that there is significant scope for them to trade and share risk through share tenancy in the ICRISAT villages. Hence, the observed negative relation between risk and incidence of share tenancy is not due to the non-existence of the risk-sharing motive, but to the fact that the observed outcome is a 'reduced form' relation.

More generally, our contribution is to show that the Principal-Agent framework may fail to capture the existing social and economic relations in some agrarian economies, and to propose a different framework that better fits the data. While the focus of the paper is on the positive economic question of contract choice, it also has a policy implication. For a long time, share tenancy has been considered a deplorable way in which landowners exploited landless tenants, and many countries have forbidden its practice.[2] However, if tenants choose the contracts they sign, and market forces efficiently select tenants and landlords in specific contractual arrangements, then it may not be welfare improving to eliminate share tenancy as it matches landlords and tenants with complementary features and compatible needs. Therefore understanding how the market for land contracts works in these villages is of crucial importance in order to decide future policies. Also, if share tenancy is indeed chosen for its risk-sharing features, then its forceful elimination in developing countries where insurance markets are absent or limited may actually worsen the welfare of those economic agents for whom the policy is intended.

The rest of the chapter is structured as follows. Section 2 discusses the main weaknesses

[2] In 1955 the Indian government approved the Land Reform Act enabling registered share tenants to claim permanent and inheritable incumbency rights to the plots taken up under share tenancy, and capping the landlords' share to 25 percent. The ultimate purpose of the Act was to eradicate share tenancy.

of agency theory when applied to land contracts and describes in more details the alternative theoretical model. Section 3 presents the predictions of the principal-agent framework tested in the empirical analysis, while Section 4 develops the econometric structural model. In Section 5 we describe the data and how we construct crucial variables. Finally Section 6 presents the results and Section 7 concludes.

2.2 Moral Hazard Models: Theory and Evidence

The first application of the principal-agent framework to the analysis of land contracts is Stiglitz (1974), which addresses the issue of moral hazard in tenants' effort. At the core of the model is the idea that if output is uncertain, the landlord cannot verify the effort provided by the tenant unless he closely monitors farming activity. If monitoring is costly, tenant's effort has to be elicited through the structure of the contract offered, by linking his payoff to the final output. This mechanism of incentive provision, however, exposes the tenant to farming uncertainty, and if the tenant is risk averse, then it may become too costly for the landlord to provide high-powered incentive and at the same time satisfy the participation constraint of the tenant. The choice between wage contract, share tenancy and fixed rent contract is then dictated by the trade-off between incentive provision and insurance. When uncertainty increases, the risk-bearing motive becomes more important, and the landlord is more likely to switch from the fixed rent contract, which is the best incentive-wise, to a less powered contract such as share tenancy. Eventually, in extremely risky environments, it may even be optimal for the landlord to thoroughly give up on incentive provision and fully insure the tenant by offering a wage contract. This canonical set up, therefore, predicts that the incidence of share tenancy with respect to fixed rent contracts depends positively on output risk, while the probability of observing share tenancy relative to wage contracts should decrease with risk.

More recently, many efforts have been made to incorporate more realistic features of agrarian economies into this basic framework. Ghatak and Pandey (2000) study the optimal contract when there is joint moral hazard in productive effort, which affects the mean of the output distribution, and in risk-taking behavior, which affects the spread of the distribution. Such moral hazard in risk from the tenant's side is induced by the presence of the limited liability clause by which the tenant cannot be held responsible for the rent if his income (or wealth) at the end of the cropping season is below some threshold. Such a clause makes the tenant act as a risk-lover agent and induces a form of moral hazard in risk-taking behavior, such as choice of crops, use of fertilizer and water resources, and more general farming decision making.[3] The main results of their study are that: a) the wage contract is never offered by the landlord, and b) share tenancy is more likely to be observed over fixed rent contracts if moral hazard in risk is more severe than moral hazard in effort. The intuition is that even though the wage contract eliminates the moral hazard in risk, it has a severe incentive problem. Hence the share tenancy contract is always better than a wage contract, as the resulting increase in effort dominates the increase in risk. Between share tenancy and fixed rent contract, the choice is dictated by the relative importance of the two types of moral hazard. If moral hazard in risk is relatively more severe, then the landlord finds optimal to discourage risk-taking behavior through share tenancy at the cost of reducing incentive on effort. The key point therefore is that if moral hazard in risk is present, riskier

[3]Basu (1992) first studied the effect of limited liability on the optimal contract.

farming techniques would be associated with fixed rent contracts.

The empirical literature on sharecropping focused on the relation between risk and contract choice in order to test the main predictions of the principal-agent model with moral hazard. In Rao (1971) and Allen and Lueck (1992, 1995, 1999) very different contemporaneous agrarian economies (semi-arid Indian villages and North-American farms respectively) are studied and the results show that sharecropping is more frequently observed than fixed rent contracts when less risky crops are cultivated. Under the hypothesis that crops planted are exogenously determined, the authors conclude that share tenancy is more commonly chosen in less risky environments, contrary to the theoretical prediction. In Ackerberg and Botticini (2000), where attention is focused on historical Italian data, riskier crops are instead found to be more likely observed under sharecropping.

Ackerberg and Botticini (2001) attempt to reconcile these empirical results with the theoretical predictions by arguing that the econometric specifications may suffer from endogeneity bias due to the agents' matching and the intertwining of the moral hazard and risk-sharing motives. Given that in a moral hazard framework there may be incentives for heterogeneous tenants to match with particular landlords, correlation in personal characteristics may cause biased estimates if some characteristic is partially observed or poorly proxied, so that the true effect of risk on contract choice may be obscured by incentive on matching. They approach the problem by proposing a reduced form matching equation to estimate jointly with a contract choice equation and find evidence that *less risk averse tenants are more likely to accept fixed rent contracts*, hence concluding that there are significant incentives on matching based on agents' attitude towards risk. However, even after controlling for endogenous matching, they find that *the effect of cultivation risk on the type of contract offered by the landlords* may or may not be significant depending on the instruments set and functional forms used, so that again there is no strong evidence in favor or against the principal-agent model predictions.

A problem common to all the empirical papers cited, however, is the maintained assumption that crop choice is exogenous, so that riskiness of the crop cultivated on a specific plot is an adequate measure of exogenous uncertainty. But if the crop planted is chosen by the farmer, then a result such as the one found by Allen and Lueck does not necessarily contradict the principal-agent model. It may instead be compatible with a principal-agent framework with joint moral hazard in effort and risk, where fixed rent contracts are indeed associated with riskier farming techniques, such as the crop planted.

Different in flavor, the work by DeWeaver and Roumasset (2001) calibrates and simulates a principal-agent model with moral-hazard in effort using Philippines data. They show that the model fails to replicate the observed distribution of contracts, and hence conclude that "the canonical theory is rejected at the 0% significance level" (page 19).

Even though the existing empirical evidence cannot conclusively refute the principal-agent framework, doubts arise on its adequacy for describing modern agrarian economies. One of the key aspects of the principal-agent set up is that even if landlords are heterogeneous and offer different contracts, these are always utility equivalent for the tenants to their outside option, since the tenant's participation constraint is typically binding. Hence, if in equilibrium contracts generate a surplus, this is gained exclusively by the landlords, and tenants are left with their reservation utility. This may seem to be driven by a perfectly elastic supply of tenants. However, as argued in Bell (1989), this is not enough. Even if the supply of tenants is large compared to landlords, tenants can still have bargaining power in sharing the surplus if their refusal can 'hurt' the landlord. If landlords have outside options and incur an opportunity cost when meeting tenants, then a refusal can indeed be harmful and landlords may find it profitable to raise the offer to attract the tenant. Similarly if tenants are heterogeneous in working ability, landlords may prefer to raise the offer to avoid refusals from more skilled tenants. In either circumstances the tenants hold bargaining power that could help them obtain part of the surplus.

The question is therefore in which situations the asymmetric position assigned to landlords and tenants by the principal-agent framework is a reasonable assumption. For medieval agrarian economies, such as the one studied by Ackerberg and Botticini, the relation between landless peasants and wealthy landlords might realistically be described as exploitative; but in modern societies it may be difficult to think that contracts are imposed on tenants. To restrict our attention to the case studied in this paper, casual evidence on the tenancy relation in contemporary Indian villages shows that tenants seem to enter the type of contract that best fits their personal characteristics and economic status. Sharma and Drèze (1996) describe the tenancy relationship in the North Indian village of Palanpur as a "partnership involving both conflict and cooperation", far from the exploitative stereotype. Furthermore, they show that tenants and landlords have on average the same wealth and income. Jodha (1981) finds that during the late '70s in the ICRISAT villages tenants were usually large farmers while landowners offering their land through tenurial contracts were operating on smaller scales, which "contradicts the conventional presumption, where the tenant is usually thought of as a poor and small operator while the landlord is believed to be invariably a large farmer (p.128)." Finally four of the six ICRISAT villages studied here were under the individual-based revenue collection system (*raiyatwari*) during the British rule in India. Under such system the land revenues were collected directly from the cultivator of the land, who had a legal title to it. So even though tenants did not have formal ownership rights to the land, the revenue system recognized their "actual control rights." This supports the idea that in the ICRISAT villages studied here tenants did held economic power during the British rule and most likely have maintained it after the Independence.[4]

2.3 Testing the Principal-Agent Model

Before turning to the estimates of the structural model, we estimate the type of multinomial reduced form logistic model used previously in the literature to test the Principal-Agent framework. The purpose of this analysis is to investigate whether the lack of empirical support for the agency theory is the result of using inappropriate measures of risk, that do not take into account possible endogeneity of crop choice.

The crucial point is to construct two different measures of output risk for each plot. The first measure is obtained as the output variability of the plot given its characteristics, such as soil type and location, and it should therefore pick up the exogenous cultivation risk inherent in the plots, regardless of the crop planted. The other measure of risk is instead obtained as the output variability of the crop planted on a specific plot; therefore,

[4] In other areas, such as Bengal, the British rule imposed the *zamindari* or landlord-based system, where the landlowners were in charge of revenue collection and tenants had no legal recognition. The other two ICRISAT villages studied in this paper apparently did not belong to either of these revenue systems. They were not directly under the British rule, but were part of the Nizam of Hyderabad's territory. We are grateful to Lakshmi Iyer who provided these information. Banerjee and Iyer (2001) study the effect of the land revenue systems imposed by the British rule on the contemporary agrarian performance of different districts in India.

it captures as well crop-related uncertainty and it is in line with the measures of risk used in other empirical works.

The predictions of the principal-agent model tested in the empirical analysis are:

Case 1. If crop choice is exogenous, then:

a) the two measures of risk are highly correlated;

b) the incidence of the wage contract relative to share tenancy increases with risk, and so does the incidence of share tenancy relative to fixed rent contracts, regardless of which risk measure is used.

Case 2. If crop choice is endogenous, then:

a') the two measures of risk may not be correlated;

b') the incidence of share tenancy relative to fixed rent contracts decreases when the crop-related risk increases, and decreases when the exogenous risk increases.

The rationale underlying these predictions is that if the crop planted is exogenously determined, then certain crops are more likely planted on plots with specific characteristics; hence, the two measures of risk should be correlated in response to the correlation between plot characteristics and crops planted. Furthermore, in this case there is no role for risk-taking behavior through crop choice by the tenant, while moral hazard in effort may be severe. Therefore, we would expect share tenancy to be more frequently observed than fixed rent contracts and less frequently observed than wage contracts when exogenous plot-related risk is higher, as in the canonical principal-agent model *a' la* Stiglitz. As crop planted is determined by plot characteristics, crop risk also measures an exogenous form of uncertainty, so that we would expect to find similar relations between contract choice and crop-related risk.

On the other side, if crop planted is endogenous, i.e. chosen by the tenant, then the two risk measures are not necessarily correlated. Due to moral hazard in effort we should still observe that share tenancy is more frequently observed than fixed rent contracts on exogenously riskier plots. But if moral hazard in risk-taking behavior is also present, due to limited liability, then we also would expect to find fixed rent contracts to be associated with riskier crops, while under share tenancy safer crops prevail. Hence crop-related risk should have an independent effect (and of opposite sign) from the exogenous measure of risk on the type of contract.

To test the predictions under Case 1, we estimate a multinomial model of contract choice controlling first for exogenous plot-related risk, and then for crop-related uncertainty. If the principal-agent framework is valid then we should expect the two measures of risk to have a positive effect on the probability of observing wage contracts relative to share tenancy, and a negative effect on the probability of observing fixed rent contracts relative to share tenancy. To test the predictions under Case 2, we estimate a logit model of choice between fixed rent contracts and share tenancy where we control for exogenous risk and crop-related uncertainty simultaneously as opposed to Case 1. If the principal-agent framework is valid then we would expect the exogenous risk to have a negative effect on the probability of observing fixed rent relative to share tenancy due to moral hazard in effort, and the crop-related risk to have a positive effect due to moral hazard in risk. Results are shown in Section 6.2.

2.4 The Econometric Specification of the Competitive Model

In the present section we develop the structural econometric model based on the competitive framework described in Chapter 1. The main differences are that we model one-dimensional heterogeneity for landlords and tenants. Tenants are heterogeneous with respect to farming ability, while landlords are heterogeneous with respect to their opportunity cost (or monitoring technology); landlords with good alternative business opportunities typically have a higher opportunity cost if they have to attend cultivation closely, or alternatively some landlords may be particularly bad at supervising labor so that their cost is higher. Furthermore, we also account for possible moral hazard in effort devoted for the maintenance of the plot. When agrarian contracts are for short terms, the tenant has virtually no incentives in investing effort and resources for the maintenance of the plot, which may in turn result in decreased fertility. Hence we assume that under share tenancy and fixed rent contracts, the landlords incur a *multitasking*-moral hazard cost.

In the following we first model the output function and the utilities obtained by a generic tenant i and a landlord j from the three different contracts, and derive the structural multinomial models describing their individual choices. Based on the assumption that the economy is in equilibrium, we then formulate the likelihood function. In defining the structure of the model we keep in mind the characteristics of the Indian villages whose data will be used for estimation; hence such a structural model might be unsuited to describe other economies.

a) Output

Output on a plot p at time t (Y_{pt}) is assumed to be produced by a Cobb–Douglas function of land (h_{pt}), labor (ℓ_{pt}) and capital (K_{pt}) while plot characteristics (Z_{pt}) enter as shift parameters. The error term (u) is assumed to enter the output function additively and it includes a time-independent individual effect representing the farming skills of the agent cultivating the plot (η), a time effect capturing possible correlation in output across plots due to similar weather conditions (ρ), and an idiosyncratic component independent across time and individuals capturing plot specific uncertainty (v).[5]

Since under a wage contract the landlord cultivates the land, while under share tenancy and fixed rent contract the tenant manages it, input choices are made by the landlord j and the tenant i in the respective cases. Similarly the relevant individual farming skills are the ones of the landlord j if the plot is managed under a wage contract, and of the tenant i if the plot is taken under fixed rent contract or share tenancy. Hence the final output under contract c is given by

$$Y_{pt}^{c} = \begin{cases} \left(\ell_{jpt}^{c}\right)^{\theta} (h_{pt})^{\pi} \left(K_{jpt}^{c}\right)^{\varphi} \exp(\phi Z_{pt}) + u_{jpt} \text{ if } c = W \\ \left(\ell_{ipt}^{c}\right)^{\theta} (h_{pt})^{\pi} \left(K_{ipt}^{c}\right)^{\varphi} \exp(\phi Z_{pt}) + u_{ipt} \text{ if } c = S, F \end{cases} \tag{2.1}$$

$$\text{with} \begin{cases} u_{jpt} = \eta_j + \rho_t + v_{pt} \\ u_{ipt} = \eta_i + \rho_t + v_{pt} \end{cases}$$

where W indicates the wage contract, S the share tenancy contract, and F the fixed rent contract. All components of the error term are assumed to have zero mean. To focus

[5] Additive uncertainty is important in our framework since it allows us to compare the utilities under each contract for a given agent by using mean-variance analysis without having cumbersome expressions. Such an assumption is also made in Laffont and Matoussi (1995).

on tenants' heterogeneity with respect to farming skills and landlords' heterogeneity with respect to opportunity cost, we assume that $\sigma^2_{\eta_j} = 0$, and that therefore the variance of the individual effect is due to farming skills variation across tenants. The time effect and the random component have variances equal to σ^2_ρ and σ^2_v respectively with, $cov(\rho_t v_{pt}) = 0$.

b) Contracts and input choices

Under the wage and the fixed rent contract, the landlord and the tenant respectively obtain the whole output and bear the full cost of all inputs. In both cases therefore inputs are chosen by equating their marginal product to their cost. Under share tenancy, the tenant obtains only a portion α_t of the final output, and while for some inputs he bears their full cost, the cost of other inputs is shared with the landlord. Input intensities are then decided by equating the marginal product the tenant accrues with the portion of marginal cost he bears. Inputs whose cost is fully borne by the tenant are typically underprovided.[6] This implies that input intensities are endogenous with respect to the contract form and we need to obtain demand functions for each input (labor and capital) under each contract, and use 'indirect' production functions conditional on the efficient choice of all inputs given the contract type. However, explicitly considering the demand functions of all inputs makes the econometric specification quite intractable. Also, while labor input is always provided exclusively by the tenant under share tenancy, capital input may actually include some forms of capital whose cost is shared between landlords and tenants, and some forms whose cost is fully borne by the tenants.[7]

[6] This result is known in the literature as the *Marshallian inefficiency* of share tenancy.

[7] A second level of endogeneity might affect eq.(2) if agents face individual-specific input and/or output prices. We rule out this possibility and instead assume that in a specific period t within a village all agents face the same prices.

To reduce the complexity of the structural form and to allow flexibility in terms of cost sharing rules for the different forms of capital, we use the following specification of the production function

$$Y_{pt}^{c} = \begin{cases} \left(\ell_{pt}^{c}\right)^{\theta'} \left(h_{pt}\right)^{\pi'} \exp(\beta_1 Z_{pt}) + u_{pt} \text{ if } c = W, F \\ \left(\ell_{pt}^{c}\right)^{\theta'} \left(h_{pt}\right)^{\pi'} \exp(\beta_1' Z_{pt}) + u_{pt} \text{ if } c = S \end{cases} \tag{2.2}$$

which is derived from eq.(1) after substituting the contract-specific optimal demand function for capital and where individual subscripts are omitted for simplicity. In Appendix A, we show the relation between the parameters in eq.(1) and in eq.(2). The optimal labor demand functions used for the remaining analysis are

$$\ell_{jpt}^{W} = \ell_{ipt}^{F} = \left(\frac{1}{w_t}\theta' \left(h_{pt}\right)^{\pi'} \exp(\beta_1 Z_{pt})\right)^{\frac{1}{1-\theta'}} \tag{2.3}$$

$$\ell_{ipt}^{S} = \left(\alpha_t \frac{1}{w_t}\theta' \left(h_{pt}\right)^{\pi'} \exp(\beta_1' Z_{pt})\right)^{\frac{1}{1-\theta'}}. \tag{2.4}$$

b) Utilities

Landlords and tenants are risk averse. Utility functions are exponential, implying that the absolute risk aversion coefficient is constant. Formally

$$u_{it}(I) = -\frac{1}{\gamma_1} e^{-\gamma_1 I} \tag{2.5}$$

$$u_{jt}(I) = -\frac{1}{\gamma_2} e^{-\gamma_2 I} \tag{2.6}$$

where I denotes the level of income, $u_{it}(I)$ and $u_{jt}(I)$ are the utility functions of a tenant i and a landlord j at time t respectively, and γ_1 and γ_2 are their Arrow-Pratt measures of absolute risk aversion.[8]

We turn now to the specification of the expected utilities under each contract where the expectation operator is denoted E. The total salary paid to the tenant for a season under a wage contract is w_t; α_t is the share of output accrued to the tenant under share tenancy; and finally R_{pt} is the rent paid by the tenant under a fixed rent contract for the plot p at time t. Such contract payments are considered exogenous by the agents when they make their decisions as in any competitive model, but they are clearly determined endogenously in equilibrium. However, payments are not individual-specific in the sense that if two tenants sign the same type of contract on two plots of land with same characteristics (h_{pt}, Z_{pt}), then the contract payments are equal even if the tenants have different unobservable farming skills. Hence the wage rate, the output share and the base rent are only time-specific. To simplify notation (and given that we actually do not observe the base rent in the data available) we describe the model in terms of total rent paid R_{pt} for a plot of characteristics (h_{pt}, Z_{pt}).

For tenant i the utility value attained under each type of contract is

$$V_{it}^c = \begin{cases} u_{it}\left(w_t\right) \text{ if } c = W \\ Eu_{it}\left[\alpha_t\left(\left(\ell_{ipt}^S\right)^{\theta'}\left(h_{pt}\right)^{\pi'}\exp(\beta_1' Z_{pt}) + \eta_i + \varepsilon_{pt}\right) - w_t\ell_{ipt}^S\right] \text{ if } c = S \\ Eu_{it}\left[\left(\ell_{ipt}^F\right)^{\theta'}\left(h_{pt}\right)^{\pi'}\exp(\beta_1 Z_{pt}) + \eta_i + \varepsilon_{pt} - w_t\ell_{ipt}^F - R_{pt}\right] \text{ if } c = F \end{cases} \tag{2.7}$$

where the expectation is taken with respect to $\varepsilon_{pt} = \rho_t + v_{pt}$. Under the wage contract the tenant simply gets his salary. Under share tenancy the tenant obtains his share of output

[8]Note that the coefficients of absolute risk aversion may be different for tenants and landlords ($\gamma_1 \neq \gamma_2$), but there is no heterogeneity in attitude towards risk within the groups of tenants and landlords.

and bears the cost of labor. Finally under the fixed rent contract he gets the total output, bears the labor cost and pays the rent. To provide labor the tenant has two options: he can either provide the labor himself (eventually having family members cultivating the land), or hire workers. In both cases the marginal cost of labor is the salary rate w_t, which can be interpreted as the value of the tenant's disutility if working himself.

We now define the utilities of a landlord j under the three arrangements. Under wage contract and share tenancy the landlord incurs an opportunity cost in terms of foregone earnings due to *monitoring*. Such cost arises because output is uncertain so that the tenant may shirk his effort under the wage contract, or underreport output under share tenancy. To avoid this the landlord has to supervise farming activity.[9] Furthermore under share-cropping and fixed rent contract the tenant has to decide how to allocate time and effort between production activity, whose return is the final output, and maintenance activity. If tenurial contracts are signed only for one or two cropping seasons, then the tenant has no incentive in maintaining the plot. In our villages contracts are signed for short term, so the landlord incurs a *multitasking cost* under share tenancy and fixed rent contracts, that can be interpreted as a decrease in the productive value of the plot due to lack of maintenance.

Let $M_{jpt} = \beta_2 Z_{pt} + \mu_j$ be the monitoring cost of landlord j at time t as a linear function of the characteristics of the plot Z_{pt} and of unobservable time-invariant personal characteristics affecting his opportunity cost μ_j, which is distributed across landlords with mean zero and variance σ_μ^2. While such monitoring cost is fully incurred under a wage

[9] The underlying hypothesis is that labor effort is not enforceable ex-post under any contract type, in the sense that due to uncertainty the landlord cannot condition the tenant's reward/punishment on the final output. The landlord can reduce shirking or cheating behavior by the tenant with monitoring activity, but cannot enforce the efficient level of input intensities under share tenancy. In the villages we study, in fact, landlords cannot interfere with tenants' decisions under share tenancy.

contract, the landlords bears only a portion $\delta \in (0,1)$ of such cost under sharecropping, as in this case he is only partly involved in farming.[10] The multitasking cost M'_{pt} is assumed to be a linear function of plot characteristics Z_{pt} and we assume that the landlord bears it equally under share tenancy and fixed rent contracts.[11] For a landlord j the utility value attained under each type of contract is

$$V_{jt}^{c} = \begin{cases} Eu_{jt}\left[\left(\ell_{jpt}^{W}\right)^{\theta'}(h_{pt})^{\pi'}\exp(\beta_1 Z_{pt}) + \eta_j + \varepsilon_{pt} - w_t\ell_{jpt}^{W} - M_{jpt}\right] \text{ if } c = W \\ Eu_{jt}\left[(1-\alpha_t)\left(\left(\ell_{ipt}^{S}\right)^{\theta'}(h_{pt})^{\pi'}\exp(\beta_1' Z_{pt}) + \eta_i + \varepsilon_{pt}\right) - \delta M_{jpt} - M'_{pt}\right] \text{ if } c = S \\ u_{jt}\left[R_{pt} - M'_{pt}\right] \text{ if } c = F. \end{cases} \tag{2.8}$$

If the tenants' skills are private information, this constitutes an added source of uncertainty for the landlord under sharecropping. Therefore the expectation is taken with respect to ε_{pt} and η_i.

2.4.1 Individual choices

In an occupational choice setting the choice of tenants and landlords between the three contracts available can be represented as a multinomial model. The three contracts represent the three categories of an unordered variable. Let I_{it} and I_{jt} be the indicator variables

[10] This formulation is flexible enough to incorporate the phenomenon of *absentee landlordism*. Some landlords have business in towns far from the villages where land is located; hence they establish their residence in the town and leave the management of their estates to tenants under fixed rent contracts. In our framework such landlords would have very high monitoring/opportunity cost μ_j.

[11] The multitasking cost assumed here is somewhat different from the 'land mining' hypothesis explored in Dubois (2000). There the optimal contract choice is analyzed when cultivation intensity affects land fertility and landlords can offer only short term contracts. In such case it is optimal for the landlord to offer share tenancy instead of a fixed rent contract because the former mitigates the tenant's incentive to exploit the land, implying that the exploitation cost would be higher under fixed rent contract than under share tenancy. In our model multitasking is associated with the lack of maintenance of valuable assets related to the plot and not soil exploitation, hence the cost is incurred by the landlord equally under the two contracts.

representing the choice of tenant i and landlord j respectively at time t among the available contracts $\{W, S, F\}$. Then the probability for the tenant to choose one contract over the others is

$$\Pr\left(\mathrm{I}_{it} = c | Z_{pt}, \mathbf{k}_{pt}, \sigma_\varepsilon^2, \eta_i\right) = \Pr\left(V_{it}^c \geqslant V_{it}^{c'} | Z_{pt}, \mathbf{k}_{pt}, \sigma_\varepsilon^2, \eta_i\right) \ \forall c' \neq c \tag{2.9}$$

and similarly for the landlord

$$\Pr\left(\mathrm{I}_{jt} = c | Z_{pt}, \mathbf{k}_{pt}, \sigma_\varepsilon^2, \widetilde{\sigma}_\eta^2, \widetilde{\eta}, \mu_j\right) = \Pr\left(V_{jt}^c \geqslant V_{jt}^{c'} | Z_{pt}, \mathbf{k}_{pt}, \sigma_\varepsilon^2, \widetilde{\sigma}_\eta^2, \widetilde{\eta}, \mu_j\right) \ \forall c' \neq c \tag{2.10}$$

where such probabilities are conditional on plot characteristics Z_{pt}, the vector of contract payments $\mathbf{k}_{pt} = (w_t, \alpha_t, R_{pt})$, output risk σ_ε^2 and the individual specific unobservable characteristics. For the landlords these probabilities are also conditional on the variance of the tenants' skills given the pool of tenants that have chosen sharecropping $\widetilde{\sigma}_\eta^2 = E\left(\left(\eta_i^2\right) | \mathrm{I}_{it} = S\right)$, and the average skill level of the tenants choosing share tenancy $\widetilde{\eta} = E\left(\eta_i | \mathrm{I}_{it} = S\right)$.

Given the definitions of compensating risk premium and equivalent risk premium as formulated by Pratt (1964), we can obtain thresholds for the unobservables η_i and μ_j such that the inequalities in eqs.(9)-(10) are satisfied.[12]

2.4.2 Equilibrium matching and the likelihood function

In equilibrium contract payments adjust so that both landlords and tenants sign the contract they prefer. Hence if the economy is in equilibrium the possibility of a mismatch,

[12] See Appendix B for an explanation of how these results are derived and for the exact expressions obtained for the thresholds.

meaning that a tenant or a landlord sign a contract different from his first best, given his characteristics, is ruled out, and the observation of a specific contract between a landlord and a tenant 'reveals' that: a) they both prefer the observed contract to the other possible contracts, given their matching and contract payments; and b) they prefer the observed matching to all other possible matching. Note also that landlords and tenants independently make their choices conditional on contract payments and self-select into specific contracts and matchings. Therefore, the probability of observing a contract on a specific plot is given by the joint probability that the tenant and the landlord have chosen it, and due to the structure of the model the joint probability is the product of the marginal probabilities. The likelihood of observing plot p at time t under contract c is given by

$$\pounds_{pt}^{c} = \Pr\left(\mathrm{I}_{it} = c | Z_{pt}, \mathbf{k}_{pt}, \sigma_{\varepsilon}^{2}, \eta_i\right) \cdot \Pr\left(\mathrm{I}_{jt} = c | Z_{pt}, \mathbf{k}_{pt}, \sigma_{\varepsilon}^{2}, \widetilde{\sigma}_{\eta}^{2}, \widetilde{\eta}, \mu_j\right). \tag{2.11}$$

See Appendix B for the expression of the likelihood function under the assumption that both η_i and μ_j are normally distributed. The matching process clearly generates ex-post correlation in the characteristics of the agents matched, but as we separately model the decision process of landlords and tenants, the structure of the matching is fully characterized and endogeneity is not an issue.

2.5 Data: the ICRISAT Villages

The dataset used is part of the Village Level Studies data collected by the International Crops Research Institute for the Semi-Arid Tropics in India (ICRISAT).[13] From mid-1975 till mid-1985 the Institute surveyed a panel of farming households in the Indian semi-arid tropic regions in the states of Andhra Pradesh, Maharashtra, Gujarat and Madya Pradesh.

Two villages were surveyed for each of the five districts selected to represent the different agro-climatic zones, but in only three districts data collection started from 1975 and covered all schedules (or surveys). For each of these three districts (Mahbubnagar, Sholapur and Akola) one village was followed throughout the ten years (the so called "continuous" village), while the companion village belonging to the same district was followed only until 1978 (the "closed" village). A total number of 240 households (40 for each village) were included in the initial survey sample and followed for the subsequent years. Households dropping out of the sample due to migration or death of the head of the household were replaced by a 'similar' household according to stratification within each village. Information collected is extremely varied, ranging from household's demographic characteristics, to wealth, labor and agricultural income, farming choices, etc.

Here analysis is restricted to the six villages in the districts of Mahbubnagar, Sholapur and Akola. All information on plot characteristics and production activity is retrieved from the Plot and Cultivation Summary Schedule. The ownership status of a plot is recorded as a categorical variable. In particular a plot can be 'owner-operated', 'leased-in' or 'sharecropped-in'. Plots who are owner-operated are not necessarily plots under a

[13] See Walker and Ryan (1990) (W-R henceforth) for an extensive description of data collection and analysis.

wage contract. Some of these plots may in fact be managed by the owner with the use of only family labor. To distinguish between family-operated plots and plots under wage contracts we use information contained in the Labor Utilization Schedule. Specifically we consider a plot to be operated under a wage contract if during the cropping season the owner hired *at least one attached male laborer on a full time basis.*[14]

a) Uncertainty measure

Most of the empirical literature analyzing the relation between contract choice and output risk uses crop yield coefficients of variation to proxy for farming uncertainty. This procedure has two major drawbacks. First, yield coefficients of variation include variability due to input choices, individual farming skills and idiosyncratic shocks. While the first two sources of variation are endogenous, only the last actually represents exogenous idiosyncratic farming risk.[15] Second, crop yield coefficients of variation measure the output risk of cultivating a specific crop. This is a legitimate measure of idiosyncratic risk for a given plot only if the crop planted is exogenous, i.e. determined by circumstances such as soil characteristics and/or weather. In some agrarian economies, however, the landlord and/or the tenant may be able to decide the combination of crops to plant, so that any measure of risk related to the crop cultivated on a specific plot would be endogenous. Finally yield variability is only one source of crop income risk for farmers. Barah and Binswanger (1982) analyze the relative importance of crop price and yield variability for the ICRISAT villages,

[14] Hired female labor is extensively used in farming, even at full time level. In a small number of cases female labor was the only source of hired full time labor. However we consider those plots as family-operated and not as plots under wage contracts. The reason is that in our model wage contracts constitute an alternative occupational choice to tenurial contracts. As in these villages landlords contract with men, women do not face the occupational choice set we are considering.

[15] Already in Allen and Lueck (1999) it is argued about the importance of separately identifying the endogenous and the exogenous sources of variation.

showing that indeed price variability was the dominant source of uncertainty in the irrigated areas.

We construct our measure of risk by estimating a production function conditioning on input choices and with a random individual effect. In this way we are able to a) purge the output variation due to input choices and other observable characteristics, and b) separate the variation due to idiosyncratic farming risk from the variation due to individual skills. By conditioning the estimates of the variance of the idiosyncratic error on plot characteristics such as soil type, presence of irrigation devices and district location, we obtain a measure of output risk that varies across plots, but is independent of the crops planted. The district location dummies capture the effect on output variability of the different weather conditions and rainfall variability across districts, while soil type and irrigation devices take into account the dependence of the specific plot on rainfall. We refer to this as a measure of *ex-ante* uncertainty of the plot, as opposed to the measure of *ex-post* uncertainty obtained by conditioning the variance of the random error on crop choice. Clearly if there is a high correlation between the crop planted and the characteristics of the plot, the two uncertainty measures should be highly correlated and it should not matter for our analysis which one to use. Finally as we consider value of nominal output, the estimated variance of the random error includes both yield and price variability. See Appendix C for details.

b) Contract payments

To estimate the models as defined in eq.(11) we need information about the payments associated with the three contracts, i.e. rent payments, output shares and wages. In particular not only do we need to know the payments associated with the contract actually signed on a specific plot, but also the 'shadow' payments that would have prevailed had a different contract been signed on that plot. Given that we can observe only the payments associated with the contracts actually chosen, we need to impute the implicit payments for the contracts not chosen.

Rent. There are 89 plots under fixed rent contracts over all years and villages in the sample. We have information on the actual rents paid for only 78 plots.[16] We impute the rents for the 11 unmatched plots and the plots observed under alternative contracts using the predicted values from a log-linear model estimated on the observed rents. Given that the model is specified in terms of full rent paid and not base rent, a selection problem may arise if plots with certain unobservable characteristics are more likely to be observed under fixed rent contracts. To correct for potential selection bias, we use a two-stage Heckman correction model. See Appendix C for details.

Share. We fix the shares to be always 50-50. As pointed out in W-R, there is a certain variability in the leasing conditions across and within villages. In most villages the 50-50 rule is applied but sometimes the share for the tenant is increased during the cropping season if the landlord fails to provide his share of seed and fertilizer costs. In some cases the tenants have to provide most of the input and so their share can vary between 50 and 75 percent. Recently Banerjee et al. (2000) show that until 1977 more than 80 percent of share tenancy contracts in West Bengal implied a 50-50 rule, but after 1977 tenants' shares increased as a result of Operation Barga, a program launched by the left-wing administration and aimed at implementing the Land Reform Act. Unfortunately it was impossible to obtain reliable estimates of output shares and we choose the 50-50 rule, as it is by far the most common

[16] The actual rents paid are recorded in the Transaction Schedule that collects information on all monetary and kind transactions involving the sampled households.

rule, and it is indeed the rule on which agents agree when signing the contract, though sometimes renegotiated at a later moment. Furthermore no program was ever launched in the study area to increase the tenants' share.

Wage. Our definition of attached laborer hired under an agrarian wage contract fits the description of *Regular Farm Servants* as defined in W-R. In the district of Mahbubnagar and Sholapur wages for this type of workers are a combination of cash and kind payments, while in Akola wages are only in cash. W-R documents that personal characteristics do not influence wages in any ICRISAT village and that kind and real cash wage are substantially the same across workers in the same village and have remained unchanged over the years. In our dataset wages for specific workers hired are not directly available, therefore we instrument wages with a set of village dummies.

A main limitation of our empirical analysis is the lack of personal information on agents matched. This impedes us to control for eventual heterogeneity in risk aversion within the groups of tenants and landlords, so that we can only estimate average coefficients of risk aversion.

2.6 Results

2.6.1 Summary statistics

In the upper panel of Table 1 we report the frequencies of each contract type by district and village. The unit of observation is the plot.[17] There is a great variability across

[17]A main plot can be divided by the farmer into various subplots in order to cultivate a different crop on each of them.

districts and across villages within district in the incidence of share tenancy and wage contracts. In the district of Mahbubnagar and Akola only about 10 and 21 percent of the plots are sharecropped respectively, while most plots (about 80 percent) are operated under wage contracts. In the district of Sholapur instead sharecropping is the most usual farming arrangement with 71 out of 100 plots sharecropped. In all districts only a small percentage of plots ranging from 0.4 to 7 percent is cultivated under fixed rent contracts. Note that in the district of Mahbubnagar farming risk should be relatively high because rainfall is uncertain and soil is mainly red (i.e. with low moisture retaining capacity), while in Sholapur risk is more limited as the soil has very high water retaining capacity. Hence, these figures seems to suggest that sharecropping is indeed more widespread when farming risk is lower contrary to the predictions of the principal-agent model.

In the second panel of Table 1 we report the average cultivated area, number of subplots, percentage of irrigated over cultivated area, and plot value by contract type.[18] Leased and sharecropped plots are smaller. Higgs (1973) uses plot size as a proxy for the landlord's monitoring cost, the rationale being that the bigger the plot, the easier for the laborer to 'hide' and shirk effort, and therefore according to our model less likely should the plot be managed under a wage contract. However our data do not support this logic.

Fixed rent and share tenancy plots are less irrigated and of lower value than wage contract plots, suggesting the plausibility of the multitasking hypothesis on land. Landlords may fear that under fixed rent and sharecropping contracts tenants might shirk effort on plot maintenance given that their contracts are for short term (usually one or two cropping

[18]The estimated per acre value of every plot was obtained during the survey from some knowledgeable person in the village and it was based on the plot potential sale value considering location, irrigation, topography, etc.

seasons). Therefore they prefer to keep more valuable plots or plots with better irrigation devices under their control for self-cultivation.

Next we investigate whether share tenancy is inefficient in terms of input intensities. According to the Marshallian theory, in fact, inputs whose costs are totally borne by the tenants under share tenancy should be underprovided as the tenants can accrue only a portion of their marginal product; inputs whose costs are shared between the tenants and the landlords should instead be provided efficiently. This clearly holds only under the assumption that inputs' intensities are not enforceable by the landlord. Hence by analyzing input intensities we can have an idea of the degree of moral hazard present in these villages. In Table 2 we present means and standard deviations of key input-output variables by ownership status. The unit of observation is the subplot. We include in the analysis family-operated subplots where full time hired laborers are only women and children. These plots constitutes more than fifty per cent of the observations. Average output per acre on subplots under fixed rent contracts is not statistically different from the mean output value obtained on plots which are family operated (t=1.3), while average output value under sharecropping is significantly lower (t=8.3).[19] These differences in output value cannot be explained by systematic differences in plot quality or in crops cultivated. In fact 91 percent of the plots under sharecropping have deep to shallow black soil, which is the most fertile, against 79 percent of family operated plots and 61 percent of fixed rent plots. Furthermore there is not much difference in the type of cultivated crops as in all cases cereals count for more than fifty per cent of the production. Instead there seems to be differences in the input

[19] The reason why we do not directly compare fixed rent and share tenancy contracts with wage contracts is that tenants taking up land under share tenancy or fixed rent contracts may decide to operate them at a family level, while wage contracts seem to be used by landlords who cultivate the land more intensively.

intensities. Labor, fertilizers, pesticides, organic manure, bullock power and machinery are systematically undersupplied under share tenancy, while there is no significant difference in the average use of these inputs under fixed rent contracts and in family-operated plots.[20] The use of seed seems to be lower in both fixed rent and share tenancy contracts, but the value of the seeds used depends on the type of crop planted. When comparing average seed values across contracts conditioning on the crop, there is no systematic difference across all contracts which may be explained with the practise that seeds are provided jointly by the landlord and tenant under share tenancy.[21] These findings therefore do suggest that share tenancy is inefficient *a' la* Marshall.

2.6.2 Testing the principal-agent framework

In this section we investigate whether in the ICRISAT villages crop choice is endogenous, and test the canonical predictions of the principal-agent framework.

In Table 3 we report the frequencies of crops planted by soil type. Across the different soil types there is little variation in crops cultivated. In all cases cereals are the most frequent crops (nearly 50 percent). Pulses are also frequently cultivated on all soil types with the exception of deep-shallow red soil, where oilseeds count for almost 40 percent of the crops planted. These results seem to suggest that soil characteristics affect crop choice only marginally, while farmer's decision making may play an important role.

The first panel of Table 4 shows the average *ex-ante* and *ex-post* output variance by

[20] When comparing inputs' intensity between sharecropped and family operated plots, all tests of mean equality rejected the null hypothesis at 1 percent level. When comparing the means of plots given under fixed rent contracts and family operated ones, the null could not be rejected at 5 percent for any of the mentioned inputs.

[21] This is consistent with Shaban (1987) who finds that the 'tenancy effect' for seeds is lower than for labor and bullock.

contract type and the correlation between the two measures.[22] First of all, if the crop planted was exogenously determined by plot characteristics, we would expect the two measures of risk to be highly correlated independently of the type of contract. Instead we find that the correlation is low for plots under wage and fixed rent contracts (0.42 and 0.37 respectively), while it is very high for share tenancy plots (0.71), which suggests that the two measures of output uncertainty are picking up different types of risk and that crop choice is not exogenous. Secondly, we find that fixed rent plots have significantly lower ex-ante variability than share tenancy plots (t=4.9), while plots under wage contracts are significantly riskier than the ones under share tenancy (t=18.2). This result, related to the exogenous uncertainty of the plots, suggests that the incidence of share tenancy with respect to fixed rent contracts is negatively related to risk, which contradicts the main theoretical predictions of the principal-agent framework related to moral hazard in effort. On the other side, when looking at the average ex-post measure of uncertainty by contract type, we find that share tenancy is associated with significantly lower crop-related output variance than fixed rent contracts. This seems instead to support the presence of moral hazard in risk-taking behavior by the tenant: tenants under fixed rent contracts choose combinations of crops that are riskier, while share tenants choose more conservative techniques.

To further explore the issue of endogeneity of crop choice and presence of moral hazard in risk, in the second panel of Table 4 we report the percentages of plots whose ex-ante and ex-post variability is below and above the average by contract type. Though 43 percent of wage contracts are signed on relatively less risky plots ex-ante, only 22 percent of them

[22] As a single plot of land is usually subplotted and a different crop cultivated on each subplot, the *ex-post* output variance for the plot is constructed as a weighted average of the ex-post variance measures for the crops planted, with weights given by the fractions of plot area dedicated to the specific crops.

have a relatively low measure of ex-post risk. A similar pattern applies to the plots under fixed rent contracts, while for the sharecropped plots the majority of plots have relatively low ex-ante and ex-post uncertainty. This suggests that in the ICRISAT villages crop risk is an important margin in farming decision making and that farmers cultivating under wage and fixed rent contracts are more willing to take up risk through crop choice than share tenants.

In order to test in a more formal way the predictions of the principal-agent model in the case when crop is exogenous we estimate a multinomial logit model where the dependent variable can assume all possible outcomes, i.e. wage contract, sharecropping and fixed rent contract. The results are shown in Table 5. In column (1) we control for soil and season dummies, cultivated area, plot value and presence of irrigation devices for possible multi-tasking cost, and the exogenous risk related to plot characteristics; share tenancy contract is the base. The coefficient on ex-ante risk is significant at the 1 percent confidence level for all outcomes but, contrary to the theoretical predictions, we find that the probability of observing share tenancy relative to fixed rent contracts decreases with risk. Wage contracts are, instead, found to be more frequently observed than sharecropping when risk increases, consistently with the Stiglitz model. In column (2) we use the same specification but control for risk through the crop-related measure of uncertainty and again find that risk increases the probability of observing both wage and fixed rent contracts relative to share tenancy. Hence under the assumption that crop choice is exogenous, the data reject the principal-agent framework.

To test the principal-agent model under the hypothesis that crop choice is endogenous we estimate a logit specification that controls also for risk-taking behavior by the tenant. The dependent variable now has only two outcomes, fixed rent contract vs. share tenancy, as only under such contracts the crop is chosen by the tenant. The point here is that we would like to understand whether there is risk-taking behavior through crop choice, that would invalidate the empirical practise of using crop risk as a measure of uncertainty to test the validity of the principal-agent model with moral hazard in effort. If such a risk-taking behavior exists, then we would expect the crop-related measure of risk to be significant even after controlling for exogenous risk and furthermore to have an effect on contract type opposite in sign with respect to the exogenous risk measure. Nonetheless, as there may be a certain degree of exogeneity in crop choice, the two measures may be sufficiently correlated to create a problem of multicollinearity in the regression. To avoid this we use the residuals of a regression of the ex-post over the ex-ante variance estimated *on the sample including all possible contracts*. Such measure of crop risk is therefore purged of possible exogeneity of crop choice that may exist independently of the type of contract signed on the plot, and is instead a measure of risk purely 'chosen' by the tenant. We find that both the coefficients on exogenous uncertainty and crop choice risk are significantly positive (at 5% and 1% significance level respectively), which means that there is significant risk-taking behavior by the tenant and that, even after controlling for it, the data refute the principal-agent prediction on the relation between exogenous risk and contract choice.

Given that crop uncertainty controls for risk-taking behavior by the tenant, it also controls for incentives on matching as described by Ackerberg and Botticini (2001). They argue that if tenants are heterogeneous in risk aversion, then efficiency would drive less risk-averse tenants on riskier plots under fixed rent contracts; so that the results in column

1 could be justified by heterogeneity in tenants' characteristics. However, if heterogeneity in tenants' risk aversion is controlled for, we should still observe that share tenancy prevails over fixed rent contracts on riskier plots. In such framework the choice of riskier crops would be dictated by tenants' attitude towards risk and not by limited liability. Hence, the ex-post measure of uncertainty, purged of possible correlation with the uncertainty inherent in the plot, should capture fairly well heterogeneity in risk aversion and control for such incentive on matching.

2.6.3 Structural estimates

Table 6 shows the structural estimates obtained by estimating the competitive occupational choice model using as a measure of risk the ex-ante output variance. In the second column we report the estimates of the parameters entering the production function, while in the fourth column we report the parameters related to the multitasking and monitoring costs along with the coefficients of risk aversion.

The Cobb-Douglas share of labor is 0.91 while the share of land is equal to 0.005. As shift factors we control for irrigation, district, soil, season and a time trend. The underlying assumption is that within districts agents face the same prices for inputs and output, so that variation in input choices is due only to plot characteristics. We control for monitoring cost using the size of the plot as suggested by Higgs (1973), and the exogenous riskiness of the plot. The idea is that the more uncertain the environment is, the more severe the incentive problem may be, and therefore the higher the shirking-monitoring cost associated with wage and share tenancy contracts. When uncertainty is low, instead, the landlord may be able to identify ex-post the tenants' effort and therefore link his reward to the final output, ensuring in this way the efficient level of effort without incurring any monitoring cost. Hence we should expect higher risk to be associated with higher monitoring cost. We find that plot size has a significant negative effect on the monitoring cost, contrary to what expected, while risk affects monitoring cost positively, as expected. Multitasking cost is controlled for by plot value, soil dummies and presence of irrigation devices. Soil dummies and irrigation devices capture the degree of maintenance necessary for the plot. If a well or a pump is present on a plot for irrigation, then maintenance is required to keep it in good operative conditions for future seasons. Under share tenancy and fixed rent contracts the tenant has no incentive in devoting efforts and resources for the maintenance of the irrigation devices. Hence, we would expect that the presence of an irrigation device increases the multitasking cost incurred by the landlord under such contracts and, consistently with this, we find that the coefficient on the irrigation dummy is positive and significant. The fact that the plot value still has a significantly positive effect on the multitasking cost after controlling for soil type and irrigation may be consistent with the fact that the market for land is very thin. Landowners who cannot sell their 'low' quality plots and cannot cultivate them, are more likely to rent them out either under share tenancy or under fixed rent contracts.

The estimated coefficient of absolute risk aversion is equal to 2.25 for tenants and 1.27 for landlords; they are both significantly positive and the test on their equality is rejected at 1% level ($\chi^2_{(1)} = 6.84$), meaning that tenants are significantly more risk averse than landlords. The coefficient on the variance of individual skills is 0.05 and is not significantly different from zero. Such coefficient should be equal to the constant absolute risk aversion coefficient for landlords if tenants' skills were indeed private information and constituted a source of income uncertainty for the landlord under share tenancy. From this we can conclude that information on farming ability is spread within the ICRISAT villages. Finally δ is estimated to be equal to 0.57, meaning that under share tenancy landlords devote in monitoring about half the time spent under wage contracts.

These results shows that both landlords and tenants are sensitive to the cultivation risk, and, as they are risk averse, their choice of the optimal contract is affected by risk-sharing considerations. Moral hazard in the form of shirking and multitasking cost also plays an important role in the landlords' decision of which contract to offer.

In order to see if our model can predict the observed 'reduced form' relation between contract distribution and risk, Table 7 shows the actual and predicted probabilities of each contract by district and village.[23] The predicted probabilities are fairly close to the actual ones. In the lower panel we report the actual and predicted frequencies of each contract when ex-post output variability is below and above the average. Even here the predictions capture the pattern found in the data closely. More specifically the predicted probability of observing share tenancy relative to fixed rent contracts increases with risk while the probability of observing share tenancy relative to wage contracts decreases with risk. Therefore our model can replicate the relation between the equilibrium distribution of contracts and risk. This is in sharp contrast to the inability of the principal-agent model to explain the observed pattern.

[23]Such predicted probabilities can be obtained by looking at the choice distribution of either the landlords or the tenants. We report the ones obtained from the tenants' preferences. The predicted probabilities computed from the landlords' preferences have similar patterns.

2.7 Conclusions

The existing theoretical literature analyzes the determinants of contract choice in agrarian economies using 'partial equilibrium' principal-agent models, where the shape of the contract is unilaterally determined by only one of the contracting parties. Their predictions regarding the relation between farming risk and incidence of share tenancy have been tested in a number of studies and found sometimes to be at odds with empirical evidence.

The aim of this paper is twofold. First, we tested the predictions of agency theory models taking into account possible endogeneity of crop choice, which was not considered in previous studies and, therefore, may have hindered their results. Using Indian data, we find that principal-agent models with moral hazard in effort are rejected by our data. Second, we construct a structural econometric model based on an alternative theoretical framework where both landlords and tenants choose the contract they prefer considering as given the contractual terms, as in a competitive framework. The structural estimates allow to separate the risk-sharing motive from the incentive one, and to evaluate the effect of risk on the two sides of the market. In this way we can reassess the role of risk-sharing in contract choice by looking at the effect of risk on the individual choices, while the observed relation between risk and distribution of contract is seen as the aggregate result in equilibrium of the interaction between the different agents. We find that both landlords and tenants are risk averse, hence the risk sharing motive through contract choice exists after controlling for moral hazard, and that the type of framework proposed is able to reproduce the empirical relation between contracts' incidence and uncertainty as a 'reduced form' relation.

Appendix A: Input Choices

Consider first the optimal choice of the capital input under wage contracts and fixed rent contracts. The landlord and tenant respectively choose capital intensity equating the marginal cost to the marginal output so that the demand for capital is

$$K^c_{pt} = \left(\frac{1}{r_t}\varphi(\ell^c_{pt})^{\theta}\,(h_{pt})^{\pi}\exp(\phi Z_{pt})\right)^{\frac{1}{1-\varphi}} \quad \text{if } c = W, F$$

where r_t is the price of capital. Substituting this expression in the production function (1) we obtain

$$Y^c_{pt} = \left(\ell^c_{pt}\right)^{\frac{\theta}{1-\varphi}}(h_{pt})^{\frac{\pi}{1-\varphi}}\left(\frac{\varphi}{r_t}\right)^{\frac{\varphi}{1-\varphi}}\exp(\phi Z_{pt})^{\frac{1}{1-\varphi}} + u_{pt} \text{ if } c = W, F. \tag{A1}$$

If under a sharecropping contract the cost of capital is borne exclusively by the tenant, then his demand function will be

$$K^c_{pt} = \left(\frac{\alpha_t}{r_t}\varphi(\ell^c_{pt})^{\theta}\,(h_{pt})^{\pi}\exp(\phi Z_{pt})\right)^{\frac{1}{1-\varphi}} \quad \text{if } c = S$$

and the output function becomes

$$Y^c_{pt} = \left(\ell^c_{pt}\right)^{\frac{\theta}{1-\varphi}}(h_{pt})^{\frac{\pi}{1-\varphi}}\left(\frac{\alpha_t\varphi}{r_t}\right)^{\frac{\varphi}{1-\varphi}}\exp(\phi Z_{pt})^{\frac{1}{1-\varphi}} + u_{pt} \text{ if } c = S. \tag{A2}$$

Note that the only difference between eqs. (A1) and (A2) is in the shift term which in eq.(A2) depends on the share of output in some non linear way. Calling $\theta' = \frac{\theta}{1-\varphi}$, $\pi' = \frac{\pi}{1-\varphi}$, $\exp(\beta Z'_{pt}) = \left(\frac{\varphi}{r_t}\right)^{\frac{\varphi}{1-\varphi}}\exp(\phi Z_{pt})^{\frac{1}{1-\varphi}}$ and $\exp(\beta' Z'_{pt}) = \left(\frac{\alpha_t\varphi}{r_t}\right)^{\frac{\varphi}{1-\varphi}}\exp(\phi Z_{pt})^{\frac{1}{1-\varphi}}$, then eqs.(A1)-(A2) reduce to eq.(2) in the text. Note that if there are constant returns to scale in the specification of the production function with capital, so that $\theta + \pi + \varphi = 1$, then returns to scale are constant even in the restricted Cobb-Douglas specification and $\theta' + \pi' = 1$.

Appendix B

B1. Compensating risk premium An agent is indifferent between a contract that gives him a with certainty and a contract that gives him b with certainty plus the realization of a random variable ε if

$$u(a) = Eu(b + \varepsilon).$$

By adding and subtracting a to the RHS of the equation we get

$$u(a) = Eu(a + \varepsilon - a + b).$$

For a small variance - zero mean random variable, the above equality holds if $-a + b$ is the compensating risk premium, i.e.

$$-a + b = -\frac{u''(a)}{u'(a)}\frac{\sigma_\varepsilon^2}{2}$$

If $-a+b > -\frac{u''(a)}{u'(a)}\frac{\sigma_\varepsilon^2}{2}$ then the agent prefers the risky contract as it gives him more than what necessary to compensate him for the risk.

If both the contracts involve risky payoffs, for example $a + \varsigma$ and $b + \varepsilon$, then we can first compute the equivalent risk premium for one contract

$$Eu\left(b+\varepsilon\right)=u\left(b-\left(-\frac{u''\left(b\right)}{u'\left(b\right)}\frac{\sigma_{\varepsilon}^{2}}{2}\right)\right)=u\left(c\right)$$

and then compute the compensating risk premium for the other

$$\begin{aligned} Eu\left(a+\varsigma\right) &= u\left(c\right) \\ -c+a &= -\frac{u''\left(c\right)}{u'\left(c\right)}\frac{\sigma_{\varsigma}^{2}}{2}. \end{aligned}$$

Let q_1, q_2 and q_3 be the threshold functions for tenant i when comparing W vs. F, S vs. W and S vs. F respectively. Such thresholds are functions of $\left(Z_{pt}, \mathbf{k}_{pt}, \sigma_{\varepsilon}^{2}, \Theta_1\right)$ where $\Theta_1 = \left(\theta', \pi', \beta_1, \beta_1', \gamma_1\right)$ represents the set of parameters entering tenants' utility. By substituting eqs.(3)-(4) in (7) and then using mean-variance analysis, we get the following expressions:

$$\begin{aligned} q_1 &= R_{pt} + w_t - \left(1-\theta'\right)\lambda_{pt} + \gamma_1\frac{\sigma_{\varepsilon}^{2}}{2} \\ q_2 &= \frac{w_t}{\alpha_t} - \alpha_t^{\frac{\theta'}{1-\theta'}}\left(1-\theta'\right)\lambda_{pt}' + \alpha_t\gamma_1\frac{\sigma_{\varepsilon}^{2}}{2} \\ q_3 &= \frac{R_{pt}}{1-\alpha_t} - \frac{1-\theta'}{1-\alpha_t}\lambda_{pt} + \frac{\alpha_t^{\frac{1}{1-\theta'}}}{1-\alpha_t}\left(1-\theta'\right)\lambda_{pt}' + \left(1+\alpha_t\right)\gamma_1\frac{\sigma_{\varepsilon}^{2}}{2} \end{aligned}$$

where $\lambda_{pt} = \left(\frac{\theta'}{w_t}\right)^{\frac{\theta'}{1-\theta'}} h_{pt}^{\frac{\pi'}{1-\theta'}} \exp(\beta_1 Z_{pt})^{\frac{1}{1-\theta'}}$ and $\lambda_{pt}' = \left(\frac{\theta'}{w_t}\right)^{\frac{\theta'}{1-\theta'}} h_{pt}^{\frac{\pi'}{1-\theta'}} \exp(\beta_1' Z_{pt})^{\frac{1}{1-\theta'}}$.

Similarly let p_1, p_2 and p_3 be the threshold functions for landlord j when comparing W vs. F, S vs. W and S vs. F respectively, as functions of $\left(Z_{pt}, \mathbf{k}_{pt}, \sigma_{\varepsilon}^{2}, \widetilde{\sigma}_{\eta}^{2}, \widetilde{\eta}, \Theta_2\right)$ where $\Theta_2 = \left(\theta', \pi', \beta_1, \beta_1', \beta_2, \beta_3, \gamma_2, \delta\right)$ is the set of parameters entering the landlords' utility.

Substituting eqs.(3)-(4) in (8), landlords' thresholds are

$$
\begin{aligned}
p_1 &= -R_{pt} + \beta_3 Z_{pt} - \beta_2 Z_{pt} + \left(1-\theta'\right)\lambda_{pt} - \gamma_2 \frac{\sigma_\varepsilon^2}{2} \\
p_2 &= \frac{\beta_3}{1-\delta} Z_{pt} - \beta_2 Z_{pt} - \frac{\left(1-\alpha_t\right)\alpha_t^{\frac{\theta'}{1-\theta'}}\lambda'_{pt}}{1-\delta} + \frac{\left(1-\theta'\right)\lambda_{pt}}{1-\delta} - \frac{1-\alpha_t}{1-\delta}\widetilde{\eta} - \frac{\gamma_2}{1-\delta}\frac{\sigma_\epsilon^2}{2} + \frac{\left(1-\alpha_t\right)^2}{1-\delta}\gamma_2 \frac{\widetilde{\sigma}_\eta^2 + \sigma}{2} \\
p_3 &= -\frac{R_{pt}}{\delta} + \frac{1-\alpha_t}{\delta}\widetilde{\eta} - \beta_2 Z_{pt} + \frac{\left(1-\alpha_t\right)\alpha_t^{\frac{\theta'}{1-\theta'}}}{\delta}\lambda'_{pt} - \frac{\left(1-\alpha_t\right)^2}{\delta}\gamma_2 \frac{\widetilde{\sigma}_\eta^2 + \sigma_\epsilon^2}{2}.
\end{aligned}
$$

B2. The likelihood function Individual choices are given by the following expressions for tenants and landlords

$$
\Pr\left(\mathrm{I}_{it} = c \middle| Z_{pt}, \mathbf{k}_{pt}, \sigma_\varepsilon^2, \Theta_1\right) = \begin{cases} \Pr\left(\eta_i \leqslant q_1, \eta_i \leqslant q_2\right) & \text{if } c = W \\ \Pr\left(q_2 < \eta_i \leqslant q_3\right) & \text{if } c = S \\ \Pr\left(\eta_i > q_1, \eta_i > q_3\right) & \text{if } c = F \end{cases}
$$

$$
\Pr\left(\mathrm{I}_{jt} = c \middle| Z_{pt}, \mathbf{k}_{pt}, \sigma_\varepsilon^2, \widetilde{\sigma}_\eta^2, \widetilde{\eta}, \mu_j\right) = \begin{cases} \Pr\left(V_{jt}^W \geqslant V_{jt}^S, V_{jt}^W \geqslant V_{jt}^F\right) & \text{if } c = W \\ \Pr\left(V_{jt}^W < V_{jt}^S, V_{jt}^S \geqslant V_{jt}^F\right) & \text{if } c = S \\ \Pr\left(V_{jt}^W < V_{jt}^F, V_{jt}^S < V_{jt}^F\right) & \text{if } c = F \end{cases} \tag{B1}
$$

Under the assumption that both η_i and μ_j are normally distributed, the contribution to the likelihood of plot p at time t according to the model proposed is

$$\pounds_{pt} = \begin{cases} \int\limits_{-\infty}^{\min(q_1,q_2)} d\Phi(\eta_i) \cdot \int\limits_{-\infty}^{\min(p_1,p_2)} d\Phi(\mu_j) \text{ if } c = W \\ \int\limits_{q_2}^{q_3} d\Phi(\eta_i) \cdot \int\limits_{p_2}^{p_3} d\Phi(\mu_j) \text{ if } c = S \\ \int\limits_{\max(q_1,q_3)}^{\infty} d\Phi(\eta_i) \cdot \int\limits_{\max(p_1,p_3)}^{\infty} d\Phi(\mu_j) \text{ if } c = F \end{cases}$$

Appendix C: Data

C1. Risk We model output as in eq.(1) with

$$E\left(u_{ipt}u_{i'p't'}\right) = \begin{cases} \sigma_\eta^2 + \sigma_\rho^2 + \sigma_v^2 \text{ if } i = i',\ t = t',\ p = p' \\ \sigma_\eta^2 + \sigma_\rho^2 \text{ if } i = i',\ t = t',\ p \neq p' \\ \sigma_\eta^2 \text{ if } i = i',\ t \neq t',\ p \neq p' \\ \sigma_\rho^2 \text{ if } i \neq i',\ t = t',\ p \neq p'. \end{cases}$$

where $\sigma_\rho^2 + \sigma_v^2$ represents exogenous income risk. As maximum likelihood estimation gives inconsistent estimates of σ_η^2 and σ_ρ^2 in random effects model with both individual and time effects, we control for the time-effect with a set of year/season dummies and estimate eq.(1) as a random effect model with only an individual-effect under the hypothesis that both η_i and v_{pt} are normally distributed with mean zero. We then obtain an estimate of σ_ρ^2 as the variance of the predicted values $\widehat{\rho}_t$.

To obtain the *ex-ante* measure of risk that varies across plots but is independent of crop choice, we condition the estimates of σ_v^2 on soil type, district and presence of irrigation devices and compute the sum of the squared predicted values $\widehat{\rho}_t$ by cells defined in the same way. The *ex-post* measure of uncertainty is instead constructed by conditioning $\widehat{\sigma}^2_v$ and $\widehat{\sigma}^2_\rho$ on crop and district, to capture the riskiness of the plot given the crop planted and the weather conditions of the area where the plot is located.

Finally by conditioning $\widehat{\sigma}^2_\eta$ on the village and type of contract we are able to obtain a village-specific measure of the variance of the tenants' skill conditional on the pool of tenants that have chosen sharecropping.

Results. Table A1 shows the results when estimating eq.(1) on subplot level data. The dependent variable is nominal output so that price variability is incorporated in the measure of exogenous income uncertainty. Columns 2 and 3 show the estimated coefficients and the p-values of the output equation when the variance of the random-effect v_{pt} is estimated conditional on soil type, district and irrigation dummies. Columns 4 and 5 refer instead to the specification where $\widehat{\sigma}^2_v$ is estimated conditional on crop and district dummies. In both specifications we control for season, soil, crop and district as shift factors of the production function (results not shown). We include also a time trend to control for the enhanced productivity due to technological change that may have occurred over the ten years. The time trend should also capture the inflation trend common to all districts. Time-effect is controlled for with year/season dummies, while the variance of the individual-random effect is estimated conditional on village dummies and type of contract. The effect on output of seeds, fertilizers, organic manure, pesticides is positive as expected, while the negative sign of the coefficients on bullock power and machinery is unexpected. Irrigation does not have any significant effect, maybe because irrigation devices are typically present in the areas where rainfall is most uncertain, and they act as substitutes for natural irrigation. Testing for the hypothesis of constant return to scale for labor and land, the hypothesis cannot be rejected in the first specification ($\chi^2_{(1)} = 2.6$), but it is rejected in the second ($\chi^2_{(1)} = 9.4$) at 1% level.

The estimates of the individual-effect variance conditional on contract choice used in the analysis are taken from the first specification of the production function. A test on the restriction that the coefficients on village dummies are jointly different from zero is rejected at 1% confidence level ($\chi^2_{(6)} = 32.4$), meaning that there is significant variation in the distributions of skills across villages.

C2. Rent payments We impute the rent payments for the plots observed under share tenancy and wage contracts using the following selection model. Let FR^*_{pt} be the propensity for a plot p to be under a fixed rent contract at time t and FR_{pt} be an indicator variable equal 1 when a fixed rent contract is observed and 0 otherwise. Then

$$FR^*_{pt} = \varphi Z_{1pt} + \xi_{pt} \text{ with } FR_{pt} = \begin{cases} 1 \text{ if } FR^*_{pt} \geqslant 0 \\ 0 \text{ if } FR^*_{pt} < 0 \end{cases} \tag{C1}$$

$$\ln R_{pt} = \begin{cases} \psi Z_{2pt} + \zeta_{pt} \text{ if } FR_{pt} = 1 \\ \text{unobserved if } FR_{pt} = 0 \end{cases} \tag{C2}$$

where Z_{1pt} and Z_{2pt} are plot characteristics and R_{pt} is the rent; $\xi_{pt} \sim N\left(0, \sigma^2_\xi\right)$ and $\zeta_{pt} \sim N\left(0, \sigma^2_\zeta\right)$ and $cov(\xi_{pt}\zeta_{pt}) = \sigma_{\xi\zeta} \neq 0$. Given the contract choice model proposed, the true selection equation is given by eq.(B1) where R_{pt} is replaced by the expression in eq.(C2). Eq.(C1) can instead be considered a linearized version of the selection rule. We prefer this formulation given the high non-linearity of eq.(B1) and the small variability in the dichotomous variable FR_{pt}. The number of observations under a fixed rent contract is in fact very small relative to the number of plots under share tenancy and wage contracts (89 vs. 2320).

Results. Table A2 presents the estimates of the selection model described in eqs.(C1)-(C2). The specification in the first two columns controls for cultivated area, ex-ante variance and its square, soil, district and irrigation dummies in both equations, and the identifying restriction is on plot value, individual-effect variance, and season dummies entering only the selection equation.[24] The exclusion of plot value from the structural equation is justified by the fact that the other regressors included (soil type, irrigation and district) already capture the characteristics of the plot that may affect the rent. In the selection equation, instead, the plot value might have an independent effect as it may capture the multitasking cost potentially incurred with fixed rent contracts: better plots might be less likely to be given under fixed rent contracts because they might be deteriorated by the tenant and their value may decrease. Also there is no theoretical reason why individual-effect variance should affect the rent, while it affects the landlord's income distribution under share tenancy and hence affects the probability of observing fixed rent contract. The soil dummies were jointly significantly different from zero in the structural equation ($\chi^2_{(3)} = 13.9$), while district dummies were not ($\chi^2_{(2)} = 1.2$) as well as the coefficients on output variance and its square

[24] Season dummies were originally included in the structural equation but not found jointly significant and therefore excluded as their standard errors were high.

($\chi^2_{(2)} = 3.0$). The coefficient on cultivated area is positive in the structural equation as expected, and significant at the 10 percent level. The coefficient on the Mills ratio is not significantly different from zero.

In columns 3 and 4 we try a more parsimonious specification, given that we have only 78 observations on which to estimate the structural equation. We exclude the output variance and its square, and the district dummies from the structural equation; we also exclude the square of the output risk and the individual variance from the selection equation. The main difference with the previous specification is that the coefficient on the Mills ratio is now positive and significantly different from zero at 10 percent level, meaning that plots which are more likely to be under a fixed rent contract are also more likely to have a higher rent. We use the estimates in column 3 to predict the rents that would have been paid for plots under share tenancy and wage contracts had the parties agreed on a fixed rent contract.

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Table 1: Means of key variables by main plots
(standard deviations in parenthesis)

	Wage contract	Fixed-rent	Share-crop
Plots (%)	57.0	3.7	39.3
DISTRICT (Village)			
Mahbubnagar	**82.0**	**7.9**	**10.1**
Aurepalle	89.0	**8.9**	**2.1**
Dokur	56.1	**3.8**	**40.1**
Sholapur	**28.4**	**0.4**	**71.2**
Shirapur	20.4	**0.4**	**79.2**
Kalman	37.4	**0.4**	**62.6**
Akola	**74.5**	**4.7**	**20.8**
Kanzara	75.9	**5.7**	**18.4**
Kincheda	69.0	**0.7**	**30.3**
Cultivated area (acrs)	4.04 (3.56)	2.74 (1.77)	3.38 (3.21)
No. subplots	1.61 (0.98)	1.13 (0.42)	1.36 (0.80)
Irr/cult area (%)[1]	0.30 (0.44)	0.10 (0.30)	0.10 (0.29)
Per acre plot value[2]	25.44 (15.75)	16.84 (14.12)	20.43 (13.40)
Total	1373	89	947

[1] Percentage of irrigated area over cultivated area
[2] Plot value is in 100 Rupies.

Table 2: Means of key variables by subplots[3]
(standard deviations in parenthesis)

	All	Owner-operated: Family operated	Owner-operated: Wage contract	Fixed-rent	Share-crop
Plot (%)		57.9	26.0	1.2	14.9
Cultivated area (acrs)	2.10	1.79	2.50	2.46	2.57
	(2.25)	(1.94)	(2.56)	(1.65)	(2.63)
Output per acre (vl)	0.58	0.55	0.79	0.42	0.31
	(0.95)	(1.02)	(0.97)	(0.43)	(0.51)
Labor per acre (hrs)	285.84	276.75	383.78	213.61	155.88
	(433.3)	(434.9)	(479.4)	(221.4)	(292.8)
Seed per acre (vl)	0.047	0.048	0.056	0.021	0.028
	(0.23)	(0.29)	(0.12)	(0.020)	(0.11)
Fertilizer per acre (vl)	0.034	0.027	0.062	0.034	0.012
	(0.089)	(0.083)	(0.109)	(0.063)	(0.052)
Organic manure per acre (vl)	0.015	0.015	0.023	0.006	0.002
	(0.064)	(0.064)	(0.078)	(0.024)	(0.021)
Pesticides per acre (vl)	0.003	0.002	0.007	0.002	0.0008
	(0.025)	(0.023)	(0.036)	(0.014)	(0.010)
Bullock power per acre (hrs)	43.10	40.47	58.49	42.56	26.47
	(58.03)	(56.96)	(68.45)	(36.58)	(31.47)
Bullock power (dummy)	0.98	0.98	0.99	1.00	0.98
Machinery per acre (vl)	0.049	0.052	0.053	0.008	0.034
	(0.19)	(0.22)	(0.16)	(0.03)	(0.16)
Machinery (dummy)	0.29	0.26	0.41	0.29	0.20
Irrigated (dummy)	0.26	0.24	0.37	0.10	0.12
Soil (dummy):					
deep-medium black	0.53	0.51	0.57	0.53	0.53
medium-shallow black	0.27	0.28	0.21	0.08	0.38
deep-shallow red	0.14	0.14	0.19	0.38	0.03
gravelly, saline, sandy	0.06	0.07	0.03	0.01	0.06
Crop (dummy):					
oilseeds	0.13	0.13	0.16	0.16	0.06
cereals	0.54	0.53	0.53	0.58	0.58
fiber-crops	0.11	0.10	0.15	0.16	0.07
pulses	0.16	0.16	0.09	0.09	0.26
vegetables	0.05	0.06	0.06	0.01	0.03
sugarcane	0.01	0.02	0.01	0.00	0.00
>1 crop	0.36	0.37	0.34	0.59	0.34
Total	8537	4946	2220	99	1272

[3] Values are in 1000 Rupies.

Table 3: Crop choice and soil type

Crops	Soil type			
	Deep-medium black	Medium-shallow black	Deep-shallow red	Gravelly, saline and sandy
Oilseeds	6.7	10.7	39.1	12.8
Cereals	53.0	57.6	53.3	49.2
Fiber-crops	15.6	**8.8**	**1.1**	0.2
Pulses	14.7	**20.3**	**4.1**	31.8
Vegetables	8.0	2.0	2.4	5.6
Sugarcane	2.0	0.6	0.0	0.4
Total	100	100	100	100

Table 4: Tenancy contracts and output variance

	Wage contract	Fixed-rent	Share-crop
Mean variability by contract type			
Ex-ante variance:	0.44 (0.32)	0.33 (0.17)	**0.22** **(0.18)**
Ex-post variance:	0.41 (0.16)	0.42 (0.10)	**0.21** **(0.14)**
Correlation:	0.42	0.37	**0.71**
Frequency of contracts by variability			
Ex-ante variance:			
Below mean variance	43.12	55.06	**78.35**
Above mean variance	56.88	44.94	**21.65**
Ex-post variance:			
Below mean variance	22.51	11.24	**77.30**
Above mean variance	77.49	88.76	**22.70**
N. obs.	1373	89	947

Table 5: Contract choice logistic models

Dependent variable: Contract type (p-values in parenthesis, * significant at 1%, ** significant at 5%)	(1)	(2)	(3)
Wage contract			
Total area	0.493* (0.00)	**0.012*** (0.01)	
Plot value	0.013* (0.00)	0.008** (0.04)	
Irrigation device (dummy)	0.455* (0.01)	**1.016*** **(0.00)**	
Ex-ante risk	3.199* (0.00)		
Ex-post risk		**5.825*** **(0.00)**	
Constant	-18.623* (0.00)	-19.621* (0.00)	
Fixed rent contract			
Total area	-0.212* (0.00)	-0.260* **(0.00)**	-0.208* (0.00)
Plot value	-0.036* (0.00)	-0.040* (0.00)	-0.028** (0.03)
Irrigation device (dummy)	-0.771 (0.14)	**-0.103** **(0.80)**	0.707 (0.26)
Ex-ante risk	3.341* (0.00)		2.680** (0.02)
Ex-post risk		6.026* (0.00)	
Constant	-17.953* (0.00)	-18.986* (0.00)	-16.435* (0.00)
Ex-post risk (residuals)			8.251* (0.00)
Pseudo-R^2	0.1982	0.2538	0.3764
Log-likelihood	-1563.30	-1454.89	-189.27
No. Obs.	2409	1036	1036

In all specifications season and soil dummies are included.
Model (1): multinomial logit model, share tenancy is the base, with ex-ante variance.
Model (2): multinomial logit model, share tenancy is the base, with ex-ante variance.
Model (3): logit model for dichotomous variable equal to 1 if fixed rent contract is observed, equal to 0 if share tenancy is observed.
Ex-post risk variable is constructed as the residuals of a regression of ex-post output variance over ex-ante variance.

Table 6: Structural estimates

Dependent variable: contract type
Log-likelihood:-3546.83; N. obs. 2409
(p-values in parenthesis; * significant at 1%, ** significant at 5%)

Variables	Coefficients	Variables	Coefficients
Production function[4]:		Monitoring cost:	
Cultivated area (share)	0.005* (0.00)	Cultivated area	-0.063* (0.00)
Labor hours (share)	0.917* (0.00)	Ex-ante risk	2.473* (0.00)
β_1:		Constant	-1.509* (0.00)
Irrigation (dummy)	0.073* (0.00)	Multitasking cost:	
Time trend	0.092* (0.00)	Plot value	0.007* (0.00)
Constant	-6.314* (0.00)	Irrigation (dummy)	0.538* (0.00)
β_1':		Deep-medium black soil	-0.176 (0.06)
Irrigation (dummy)	0.293* (0.00)	Medium-shallow black soil	-0.224* (0.01)
Time trend	0.086* (0.00)	Deep-shallow red soil	-0.610* (0.00)
Constant	-6.392* (0.00)	Gravelly, saline, sandy	0.139 (0.13)
		Preferences:	
		Tenant CARA	2.249* (0.00)
		Landlord CARA	1.269* (0.00)
		Skill variance	0.039 (0.67)
		Delta	**0.575* (0.00)**

[4] Village, soil and season dummies are included.

Table 7: Actual and predicted probabilities:
(predicted probabilities in brackets)

	Wage contract	Fixed-rent	Share-crop
DISTRICT (Village)			
Mahbubnagar	**82.0** **(83.2)**	**7.9** **(7.4)**	**10.1** **(9.4)**
Aurepalle	89.0 (90.2)	**8.9** (9.5)	**2.1** **(0.3)**
Dokur	56.1 (57.2)	3.8 (0.2)	**40.1** **(42.6)**
Sholapur	**28.4** **(29.7)**	**0.4** **(0.3)**	**71.2** **(70.0)**
Shirapur	20.4 (18.9)	0.4 (0.0)	**79.2** **(81.1)**
Kalman	37.4 (36.3)	**0.4** (0.7)	**62.6** **(63.0)**
Akola	**74.5** **(78.7)**	**4.7** **(1.5)**	**20.8** **(19.8)**
Kanzara	75.9 (80.4)	5.7 (1.5)	**18.4** **(18.0)**
Kincheda	69.0 (71.7)	0.7 (1.2)	**30.3** **(27.1)**
Ex-ante variance:			
Below	42.8 (45.1)	**3.5** (3.2)	**53.7** **(51.5)**
Above	76.1 (73.6)	3.9 (2.7)	**20.0** **(23.7)**
Total	1373	89	947

Table A1: Estimates of Cobb-Douglas production function

Dependent variable: output value (1000 Rupies)
(* significant at 1%, ** significant at 5%)

Variables	(1)		(2)	
	Coefficient	P-values	Coefficient	P-values
Cultivated area (share)	0.216*	0.00	0.235*	0.00
Labor hours (share)	0.810*	0.00	0.815*	0.00
Seed value	0.236*	0.00	0.243*	0.00
Bullock power (hrs)	-0.00067*	0.00	-0.00077*	0.00
Machinery value	-0.045*	0.00	-0.056*	0.00
Fertilizer value	0.306*	0.00	0.299*	0.00
Organic manure value	0.174*	0.00	0.177*	0.00
Pesticide value	0.392*	0.00	0.452*	0.00
Irrigation (dummy)	-0.011	0.55	0.013	0.47
Plot value	0.005**	0.04	0.005**	0.04
>1 crop	-0.062*	0.00	-0.083*	0.00
Time trend	0.076*	0.00	0.072*	0.00
Constant	-5.460*	0.00	-5.539*	0.00
N. obs.	8537		8537	
Log-likelihood	-6563.36		-6764.32	

In both specification: season, soil, crop and district dummies are included; time-effect is proxied by year and season dummies; individual effect variance is conditional on village and contract type.
Model (1): random-effect variance is conditional on soil, district and irrigation dummies.
Model (2): random-effect variance is conditional on crop and district dummies.

Table A2: Estimates of selection model for rent payments (two-step estimation)

Variables	Dependent variable[5]: (a) natural log of rent (structural eq.) (b) fixed rent contract vs. others (selection eq.) (p-values in parenthesis, * significant at 1%, ** significant at 5%)			
	(1)		(2)	
	(a) Structural	(b) Selection	(a) Structural	(b) Selection
Cultivated area	0.392 (0.08)	-0.131* (0.00)	0.215 (0.08)	-0.130* (0.00)
Ex-ante variance	24.702 (0.45)	-15.036** (0.04)		-0.125 (0.86)
Ex-ante variance^2	-6.123 (0.63)	6.053** (0.04)		
Soil dummies:				
Deep-medium black	-2.632 (0.20)	0.780 (0.14)	-1.810 (0.032)	0.414 (0.42)
Medium-shallow black	-2.304 (0.42)	-0.768 (0.24)	-4.309** (0.03)	-0.061 (0.90)
Deep-shallow red	-6.910** (0.03)	1.754* (0.01)	-4.403* (0.01)	0.690 (0.17)
Irrigation (dummy)	-8.813 (0.24)	3.009 (0.10)	-3.232* (0.00)	-0.607 (0.13)
District dummies:				
Mahbubnagar	6.092 (0.43)	-3.271 (0.06)		0.127 (0.72)
Sholapur	9.422 (0.32)	-4.510* (0.01)		-1.215* (0.00)
Plot value		-0.019* (0.00)		-0.018* (0.00)
Individual-effect variance		0.182 (0.99)		
Season dummies:				
Kharif		0.151 (0.74)		0.215 (0.64)
Rabi		0.012 (0.97)		0.023 (0.96)
Constant	-8.515 (0.44)	4.015 (0.14)	-2.514 (0.22)	-1.233 (0.11)
Mills lambda	-0.953 (0.60)		1.109 (0.08)	
N. obs.	78	2309	78	2309

[5] Values are in 1000 Rupies.

Chapter 3

Misinformation and Retirement Wealth: Re-estimating the Effect of Pension Wealth on Private Wealth

3.1 Introduction

The basic life-cycle model of consumption predicts that, in an actuarially fair social security system, social security wealth and private wealth are perfect substitutes. If pension benefits are more generous (and hence contributions to the system are higher), then individuals reduce savings by the exact amount of the increased contributions. Private wealth is then offset by social security wealth in a one-to-one ratio. Extensions of the basic theoretical framework, that include endogenous retirement age, liquidity constraints and uncertain life span, have shown that the substitution between the two forms of wealth may actually be imperfect. Since the seminal work by Feldstein (1974), an impressive number of studies have tried to test the hypothesis of perfect substitutability by focusing on the relationship between private and social security wealth, or savings and pension contributions. Even though the estimates of the offset effect vary substantially across studies, a common finding is that the displacement is far from one, which seems to reject the life-cycle model.

In this chapter we identify two additional reasons that may have caused previous estimates of the offset effect to be biased, and develop a methodology that overcomes both problems. First, current wealth holdings are functions of the past expectations that agents held about their social security or pension wealth. There is evidence that individuals have expectational errors about their retirement benefits and these are systematically related with the true pension entitlements.[1] We show that if individuals have imperfect information about their retirement benefits and the expectational errors are correlated with their social security or pension wealth, then estimates of the offset effect, based on econometric specifications where current private wealth is the dependent variable, suffer from endogeneity bias. Second, expectational errors about retirement benefits imply that agents have expectational errors on the rate of return of their pension contributions. The offset effect of contributions on savings is then a function of the internal rate of return implied by individuals' expectations on future pension wealth, and is therefore different from one even if the system is actuarially fair.[2]

[1]See Bernheim (1987, 1988, 1990) and Gustman and Steinmeier (1998, 1999, 2001).

[2]According to the standard definition of internal rate of return, this is the rate that equates the present value of the contributions paid with the present value of the expected retirement benefits.

The contribution of this chapter is to take as a starting point the empirical facts related to the individuals' expectational errors about thier pension entitlements, and provide an alternative econometric model that allows to test whether individuals substitute private wealth with pension wealth in a way that is quantitatively consistent with the life-cycle hypothesis, avoiding the problems incurred by the existing empirical literature. Since current wealth depends on how agents updated in the past their expectations on social security wealth, there is little hope to extract information on the extent of the offset effect using current wealth and currently expected social security wealth. This suggests, however, that current wealth can be used as a conditioning variable to control for all the information on past expectations and consumer behavior, that the econometrician cannot observe. Saving equations (or consumption equations) represent the optimal consumer's choice given the retirement benefits' expectations currently held, and as such they contain the information on what is the optimal level of wealth that the individual plans to hold before entering retirement. The empirical strategy we propose is, therefore, to project the level of wealth that the individual plans to hold at retirement by using information on his current consumption level and planned consumption growth rate, and test for the offset hypothesis by exploiting variability in projected wealth and expected pension wealth, controlling for past behavior and expectations through current wealth holdings.

We adopt the proposed methodology on data from the Bank of Italy Survey of Household Income and Wealth (SHIW). We use the pooled panel components for the years 1989-91 and 1991-93 as they offer information on expected Social Security wealth, expected income growth and variance. Furthermore our findings can be directly compared with the results in Jappelli (1995) who uses the same data to test for perfect offset using the canonical specification. We find that the offset effect of Social Security wealth on private wealth is smaller than what the life-cycle model predicts, even taking into account retirement effects, but there is significant heterogeneity.

The plan of the chapter is as follows. In section 2 we review some stylized facts on the extent of misinformation about retirement benefits, while in Section 3 we discuss the problem arising when wealth and saving equations are estimated to quantify the offset effect and show how projected wealth can be used to test for the offset effect. In Section 4 we develop the econometric model. Finally section 5 and 6 describe the data and report the empirical results. Section 7 concludes.

3.2 Knowledge about Retirement Benefits: Stylized Facts

In the last fifteen years a number of papers have documented the extent to which individuals know about their Social Security and private pensions' entitlements at retirement. The earliest work is by Bernheim (1988, 1990), who used the Retirement History Survey (RHS) to retrieve information about expected retirement benefits and actual benefits received once the individuals retired. More recently, the possibility of linking data from the Health and Retirement Survey (HRS) with Social Security records and with employer-provided information on private pension plans has allowed Gustman and Steinmeier to document the extent of misinformation, and to study whether informational errors are systematically related with retirement benefits.[3] In the following we summarize some of their main findings.

- *Fact 1: Misinformation about future retirement benefits is widespread.* In the 1992

[3] See Gustman and Steinmeier (1999, 2001).

wave of the HRS, 51 percent of the respondents report that they do not know their future Social Security annual benefits. Among those who venture a guess, 72 percent have an expectational error greater than $1,500 on an annual basis. Similarly, 40 percent of the individuals enrolled in a defined benefit pension plan state that they do not know their pension value, i.e. the present value of expected benefits from the date of expected retirement forward. Among the individuals who report their expected pension value, 60 percent report a value which is half or twice as large as the value computed from the provider's records. Individuals enrolled in defined contribution pension plans seem to be more informed as only 28 percent do not know their pension value, but again 70 percent of those who think they know their entitlements have a severe expectational error.

- *Fact 2: Misinformation is not random.* In Table 1 we report tabulations from Gustman and Steinmeier (2001). Respondents are sorted according to the ratio of Social Security or private pension wealth over their total wealth. In the first four columns, we report the percentage of respondents who do not know their retirement benefits (DK), those who underestimate their benefits by more than 25 percent of their calculated benefits ($< 75\%$), those who overestimate them by more than 25 percent ($> 125\%$), and those who estimate their benefits within the 25 percent range ($75 - 125\%$). In columns 5-7 the percentages are computed excluding the 'Don't know' (our calculations). The upper part of the table refers to Social Security benefits, while the lower part refers to private pensions. First of all, there is a pronounced tendency to underestimate retirement benefits. As noted in Gustman and Steinmeier (1999), this is a recent phenomenon, as in the previous decade "there was an important subgroup of respondents who was overly optimistic about its benefits" (pag. 41). Furthermore, misinformation is systematically related with the size of Social Security and private pension coverage. As the ratio of Social Security wealth over total wealth increases, the percentage of individuals who do not know their future Social Security benefits increases significantly, implying that those who will rely more heavily on Social Security, to support themselves over the retirement years (i.e. the lower rows), know the least. This pattern is reversed in the case of private pension. Finally, the percentage of individuals underestimating their private pension benefits increases substantially as the ratio of pension wealth to total wealth increases. Among those who guess their pension benefits, 37.6 percent underestimate their benefits and 40.4 percent overestimate them when the pension wealth to total wealth ratio is below 20 percent; when instead the pension wealth is at least 60 percent of the total wealth, the percentage of those underestimating becomes 61.8 percent, while only 12.3 percent overestimate their benefits. In the case of Social Security, instead, the groups with relatively higher and lower Social Security wealth to total wealth ratio seem to have greater expectational errors, while there is no clear relation between the size of the Social Security wealth and the sign of the expectational error.

- *Fact 3: Older workers are better informed.* Not only are older workers more likely to give an estimate of their retirement benefits, but they are also more likely to have an expectational error lower than 25 percent of the true value. Bernheim (1988) regresses actual Social Security benefits over expected benefits and age, also controlling for various socio-economic factors, and finds that, when approaching retirement, individuals tend to make more accurate forecasts about their benefits. This suggests that over time workers update their expectations and that, the closer to retirement they get, the more informed they are, possibly due to more intense planning activity.

- *Fact 4: Individuals' response to information update is consistent with economic incentives.* When regressing the difference between actual and planned retirement age over the expectational error on Social Security wealth, Gustman and Steinmeier find that individuals who initially overestimate their benefits are more likely to retire later than planned, after controlling for socio-economic characteristics. When looking at the relation between planned anticipated retirement and expectational errors, they also find that those who initially underestimate their benefits are more likely to stick to their early retirement plans over a six year horizon. This suggests that individuals adjust their plans as they gather new information on their retirement resources.

Why is misinformation so widespread? And why is it related with the Social Security and pension coverage? To the best of our knowledge there is no theoretical model of information acquisition in the retirement literature that explains all these empirical findings in a unified framework. Lusardi (2001) explores the idea that gathering information on the Social Security/pension formula and making calculations can be a costly and complicated task.[4] The effort devoted to this task affects the quality of the information available in every period, and the precision of the expectations. She points out that individuals may differ substantially in their cost of acquiring and processing information, and they may

[4]Only recently, for example, the Social Security Administration in the US has started mailing financial statements to the covered individuals with details about their future benefits.

therefore decide to devote different levels of effort for such an activity. Borrowing from the literature on hyperbolic discount, she suggests furthermore that if individuals have quasi-hyperbolic discount rate, they may decide to postpone the acquisition of information and retirement planning.[5] Though this type of models can explain why older workers are better informed, it does not shed light on why misinformation is related to retirement coverage, and more specifically why those with higher Social Security coverage are less informed, while those with higher private pension coverage are better informed. Gustman and Steinmeier (2001) resort to models of bounded rationality and argue that individuals expecting their replacement rates from Social Security to be adequate according to standard rules of thumb may 'choose' not to be informed, and are therefore more likely to correct their expectations later. Hence, individuals with higher Social Security coverage would be less informed. On the other side, it can be argued that some workers have higher private pension wealth because they have made high *voluntary* contributions beyond what pension plans typically require. These workers may be better informed since they have to decide the voluntary contribution rate. Finally, optimism at macroeconomic level, or generalized fears that the Social Security sistem may undergo unfavorable reforms, may explain why most people tend to overestimate or underestimate their retirement benefits. Taking these empirical findings as a starting point, in the next section we show the effect that the type of misinformation described above has on the accumulation of private wealth and on the estimates of the offset effect.

[5] See Harris and Laibson (2001) and O'Donoghue and Rabin (1999) for models formalizing the link between hyperbolic discount and delayed actions.

3.3 The Offset Effect and the Role of Misinformation

In this section we outline the main predictions of the life-cycle model concerning the effect of social security and private pensions on wealth, and show the limits of previous empirical research that seeks to estimate the offset effect through wealth or saving equations. To do this we present a simplified life-cycle model.

Consider an individual with a finite and certain lifetime horizon T, who receives income y_t with certainty and pays pension contributions d_t every working period until the age of exogenous retirement R. Let $E_t B_s$ be the expected retirement benefits at time t when the expectations are formed using all available information, and let $E_{it} B_s$ be the expected retirement benefits when the individual forms his expectations conditioning on a smaller information set than the one available. We use the subscript i to indicate that the information set is specific of the individual. In this model with no income uncertainty and exogenous retirement age, if the individual gathers all information about the pension system, he knows with certainty what his retirement benefits will be at retirement; hence $E_t B_s = B_s$. Suppose for the time being that gathering information is costless, so that the individual is perfectly informed, $E_{it} B_s = E_t B_s = B_s$. The individual decides the consumption path by maximizing lifetime utility subject to the following period budget constraints

$$\begin{aligned} A_{t+1} &= (1+r)\left(A_t + y_t - d_t - C_t\right) \quad \text{if } t = 1, ..., R \\ A_{t+1} &= (1+r)\left(A_t + B_t - C_t\right) \qquad \text{if } t = R+1, ..., T \end{aligned} \tag{3.1}$$

where C_t is period consumption. By combining the two, the following intertemporal budget constraint is obtained

$$\sum_{s=1}^{T}\left(\frac{1}{1+r}\right)^{s-1} C_s = \sum_{s=1}^{R}\left(\frac{1}{1+r}\right)^{s-1}(y_s - d_s) + \sum_{s=R+1}^{T}\left(\frac{1}{1+r}\right)^{s-1} B_s \tag{3.2}$$

where it is assumed that at the beginning of the life-cycle the individual had zero asset holdings. Under the assumption that the interest rate is equal to one and to the intertemporal rate of substitution, the consumption sequence that maximizes lifetime utility is constant and period consumption is equal to

$$C_t = \frac{1}{T}\left[\sum_{s=1}^{R}(y_s - d_s) + \sum_{s=R+1}^{T} B_s\right], \tag{3.3}$$

i.e. in every period the individual consumes a portion $\frac{1}{T}$ of his lifetime resources. If the pension system is actuarially fair (or balanced), then the present value of pension contributions equates the present value of retirement benefits $\sum_{s=1}^{R} d_s = \sum_{s=R+1}^{T} B_s$, and period savings and wealth accumulated up to the beginning of period $t+1$ are equal to

$$\begin{aligned} s_t &= y_t - d_t - C_t & (3.4)\\ A_{t+1} &= \sum_{s=1}^{t}(y_s - d_s) - \frac{t}{T}\left[\sum_{s=1}^{R}(y_s - d_s) + \sum_{s=R+1}^{T} B_s\right]. & (3.5)\end{aligned}$$

Furthermore the wealth accumulated up to the beginning of the retirement period is given simply by $A_{R+1} = \left(1 - \frac{R}{T}\right)\sum_{s=1}^{R} y_s - \sum_{s=R+1}^{T} B_s$, where the sum of future retirement benefits is the value of the pension wealth. Keeping the income constant, an increase in the value of the pension wealth (accompanied by a proportional increase in the contributions paid, so as to leave the pension system actuarially fair) displaces in a one-to-one ratio the private wealth accumulated *at retirement*, while increased contributions perfectly displace private savings, since consumption remains unaffected.

More complex models in the literature show that the offset effect may be different from one. Allowing for endogenous retirement, Feldstein (1974) points out that Social Security coverage in US may induce earlier retirement as it acts as a tax on earnings after the standard retirement age. If retirement is anticipated, then human wealth decreases and this may induce agents to increase savings.[6] If lifetime is uncertain, then Social Security and private pensions are insurance mechanisms against the possibility of running down private resources before death. Hence, higher expected retirement benefits reduce the need for precautionary savings, reinforcing the substitution effect. Finally, as it is not possible to borrow against Social Security wealth, individuals are liquidity constrained, and enter retirement with nonnegative 'forced' savings. The resulting offset effect is in this case lower than one.[7]

In order to obtain an estimate of the offset effect and test the hypothesis of full offset, the econometric specification typically used has been of the form

$$A_{it} = \alpha Z_{it} + \beta SSW_{it} + \varepsilon_{it} \tag{3.6}$$

where A_{it} is private wealth or the wealth/income ratio, SSW_{it} is the social security (or private pension) wealth as expected by the individual i at time t, and Z_{it} are demographic characteristics that control for the life-cycle shape of the wealth accumulation path.[8] Vir-

[6] Social Security benefits are, in fact, typically lower than wages, and individuals may compensate for the lost earnings by reducing consumption.

[7] See Gustman and Steinmeier (1998).

[8] This standard specification has been extensively used. See Feldstein and Pellechio (1979), Hubbard

tually all the existing empirical papers in the literature have tested for the complete offset by testing the null hypothesis that the estimated coefficient β is negative and equal to one.

A noticeable exception to the above specification and hypothesis testing is in Gale (1998). Deriving a wealth equation similar to eq.(5), he points out that at any period other than the retirement age the displacement effect of pension wealth on private wealth is by construction less than one, and it is a function of the marginal propensity to consume and of the life-cycle stage.[9] In his econometric specification he corrects the expected SSW variable by an adjustment factor and test the null hypothesis that the estimated coefficient on the adjusted variable is equal to minus one. His conclusions confirm that the offset is significantly less than one.

A few studies have, instead, estimated the offset effect using saving equations of the form of eq.(4), exploiting the substitutability between savings and contributions, rather than between private wealth and social security/pension wealth. Gale and Scholtz (1994) obtain an estimate of the offset effect by looking at the effect of IRA enrollment on savings. Using a utility maximizing model that incorporates the main features of IRA participation, they point out that the offset effect of IRA on private savings depends on the rates of return on IRA and private savings accounts, on tax rates and on the holding periods (due to the early-withdraw penalty on IRA savings that alters the internal rate of return on such savings), as well as on the non-IRA wealth holdings that make easier for individuals to buffer negative income shocks without recurring to early withdraws. They indeed find that the offset effect varies significantly across individuals.

(1986), King and Dicks-Mireaux (1982) and Jappelli (1995) among others, and the more recent work by Gustman and Steinmeier (1998) that uses the Health and Retirement Study.

[9] In our example this factor is equal to $\frac{t}{T}$.

3.3.1 Misinformation and Wealth Equations

Suppose now that while the individual is contributing d_s every working period to the system, he forms expectations about his retirement benefits equal to $E_{it}B_s \neq E_tB_s$. This expectational error on future benefits stems from the fact that the individual may not be perfectly informed about the pension system so that $E_{it}B_s$ represents his expectations given his limited information set at time t.[10] Let us assume that the individual underestimates his retirement benefits ($E_{it}B_s < E_tB_s = B_s$), and that individual expectations remain constant up to the beginning of period τ (with $\tau \leqslant R$), when he updates his information set and corrects his expectations about retirement benefits; hence

$$E_{it}B_s = B'_s < B_s \quad \text{for } t = 1, ..., \tau - 1$$

$$E_{it}B_s = B_s \qquad \text{for } t = \tau, ..., R.$$

His period consumption in any period $t = 1, ..., \tau - 1$ is given by

$$C'_t = \frac{1}{T}\left[\sum_{s=1}^{R}(y_s - d_s) + \sum_{s=R+1}^{T} B'_s\right] \tag{3.7}$$

while after updating his expectations about pension benefits ($t = \tau, ..., T$) his consumption

[10] Models of hyperbolic discount would consider the precision of future expectations as an endogenous variable that the individual decides upon trading off between the cost of acquiring better information and the advantage of holding more precise expectations about the future.

is equal to

$$C_t'' = \frac{1}{T-(\tau-1)}\left[\sum_{s=1}^{\tau-1}(y_s-d_s) - \frac{\tau-1}{T}\left(\sum_{s=1}^{R}(y_s-d_s) + \sum_{s=R+1}^{T} B_s'\right) + \sum_{s=\tau}^{R}(y_s-d_s) + \sum_{s=R+1}^{T} B_s\right]. \tag{3.8}$$

At age τ the individual re-optimizes his consumption path given his remaining lifetime resources; these are given by whatever was saved in the previous years (the first two terms in the squared brackets of eq.(8)), plus his remaining net income and pension benefits. The marginal propensity to consume is now $\frac{1}{T-(\tau-1)}$ as the remaining life span is $T-(\tau-1)$. Note that consumption prior to τ is below the level of consumption C_t as given in eq.(3) due to underestimation of lifetime resources. After τ, instead, consumption is higher than C_t: up to age τ the individual has 'under-used' his true lifetime resources, and can now afford higher consumption than an agent who always held perfect information.

What happens to wealth after information is updated? At the beginning of period $t+1$ the accumulated wealth is given by

$$A_{t+1}' = \sum_{s=1}^{t}(y_s-d_s) - \sum_{s=1}^{\tau-1} C_s' - \sum_{s=\tau}^{t} C_s'' \tag{3.9}$$

i.e. the income received up to age t, minus the consumption till age $\tau-1$ and the consumption from age τ till age t. Substituting eqs.(7)-(8) and rearranging the terms, the above equation becomes

$$A_{t+1}' = \sum_{s=1}^{t}(y_s-d_s) - \frac{t}{T}\sum_{s=1}^{R}(y_s-d_s) - \alpha_1(\tau)\sum_{s=R+1}^{T} B_s' - \alpha_2(\tau)\sum_{s=R+1}^{T} B_s \tag{3.10}$$

where $\alpha_1(\tau) = \frac{(T-t)(\tau-1)}{T[T-(\tau-1)]}$, $\alpha_2(\tau) = \frac{t-(\tau-1)}{T-(\tau-1)}$ and $\alpha_1(\tau) + \alpha_2(\tau) = \frac{t}{T}$. Rearranging eq.(10), we obtain

$$A'_{t+1} = \sum_{s=1}^{t}(y_s - d_s) - \frac{t}{T}\left[\sum_{s=1}^{R}(y_s - d_s) + \sum_{s=R+1}^{T} B_s\right] + \alpha_1\left(\sum_{s=R+1}^{T} B_s - \sum_{s=R+1}^{T} B'_s\right)$$

$$= A_{t+1} + \alpha_1(\tau)\left(\sum_{s=R+1}^{T} B_s - \sum_{s=R+1}^{T} B'_s\right) \tag{3.11}$$

that reduces to eq.(5) if the agent is correctly informed since the beginning, i.e. $\sum_{s=R+1}^{T} B'_s = \sum_{s=R+1}^{T} B_s$ or $\tau = 1$. If instead the individual underestimated his benefits in the past, then his wealth is higher than what a perfectly informed agent would accumulate. Furthermore, the later he updates his expectations about future benefits, the higher the over-accumulation of wealth since α_1 increases with τ.

Finally, it is interesting to notice that this over-accumulation of wealth persists even *at retirement*. The intuition for this is that from age τ the misinformed individual can afford a higher consumption throughout his remaining lifetime; this implies that the wealth necessary to sustain this higher consumption after retirement given his benefits' stream $\{B_s\}_{s=R+1}^{T}$ is higher than for a perfectly informed agent.

These results contribute to the stream of research that has studied the determinants of heterogeneity in the wealth accumulation path. It has been consistently observed that private wealth displays a significant degree of variations among seemingly observationally equivalent households. Bernheim et al. (1997) points at various factors that may explain such a variation within the life-cycle framework under the assumption of rational far-sighted agents, such as heterogeneity in time preferences, survival probabilities, income uncertainty, planned retirement age, liquidity constraints, etc. The overall conclusion of their study is that these factors can hardly count for the observed heterogeneity in private wealth, since they do not seem to be relevant. The results presented above suggest that heterogeneity in expectational errors about retirement benefits, along with different patterns of information updating, can generate cross-sectional variation in private wealth. Following Lusardi (2001), if individuals have hyperbolic discount and the rate differs across the population, then individuals with higher discount rate tend to postpone planning activity about retirement and have higher expectational errors, that will be corrected only very late in the life-cycle. The sign of the expectational error determines whether these individuals accumulate more or less wealth than their counterparts with observed similar socio-economic characteristics. Individuals who have underestimated (overestimated) their benefits in the past accumulate more (less) wealth than what the life-cycle model would predict given their *current* expectations.[11]

We now turn to the econometric problem arising when estimating the offset effect. The only information usually available to the econometrician are the current expectations on retirement benefits, while past expectations and timing of updating is unobserved. If individuals with higher Social Security or pension wealth are more likely to underestimate (overestimate) their benefits, and to revise their expectations later on, then the econometric specification in (6) suffers of endogeneity bias as the currently expected pension wealth variable would be correlated with the error term. In particular, if individuals tend to

[11] Furthermore, the pension system may give different incentives to various categories of workers about when to collect adequate information on retirement benefits. We clarify this point when describing our data and the Italian Social Security system.

underestimate their benefits, the estimated offset effect would be downward biased, as long as the agents have updated their information sometime in the past. The empirical findings laid out in Section 2 show that such a bias is likely to be present. There is indeed a systematic relation between the size of the retirement benefits and the sign of the expectational error (Fact 2), plus individuals update their expectations over time (Fact 3), so that current wealth holdings are likely to reflect past expectations unknown to the researcher. One possible way to solve this problem is by instrumenting current expectations on pension wealth. The problem with this approach is that we would need to find instruments which are correlated with current expectations but not with previous expectational errors nor with the timing of information updating. This is clearly very difficult since we still lack a testable theoretical model explaining what exactly causes misinformation, and why and when individuals decide to update their information.

3.3.2 Misinformation and Saving Equations

The key issue in estimating wealth equations to identify the offset effect is that current wealth is a state variable, and as such it depends on past information usually not observed by the econometrician. It is, however, a "sufficient statistic" for both past information sets and the economic decisions previously taken by the individual. Since agents re-optimize in every period, flow variables such as consumption and savings are, instead, functions of individuals' current expectations on lifetime resources and of state variables. In principle, therefore, it should still be possible to obtain unbiased estimate of the offset effect from saving equations. There are however some caveats.

Traditional tests of the offset hypothesis rely on the assumption of perfect information and no updating, so that consumption does not vary across individuals due to differences in the pension coverage and the only cross-sectional variability left in eq.(4) is due to the current contributions paid. In presence of imperfect knowledge, current consumption varies cross-sectionally: individuals who underestimate their benefits, have lower consumption until they update their information, while have higher consumption afterwards. Savings at any given period t can be expressed as

$$s_t = y_t - d_t - \frac{1}{T-(t-1)}\left[A_t + \sum_{s=t}^{R}(y_s - d_s) + \sum_{s=R+1}^{T} E_{it}B_s\right]. \qquad (3.12)$$

If individuals with higher pension coverage are more likely to underestimate their pension benefits, then they over-accumulate private wealth and this leads to a positive correlation between A_t and d_t in eq.(12). Hence the last term in eq.(12) needs to be controlled for.

Incidentally the empirical literature controls for wealth when estimating saving equations, because it recognizes that individuals may start their life-cycle with different wealth due to bequests, and that individual's wealth reflects a taste for savings, and therefore unobservable characteristics. But from eq.(12) it is clear that the offset effect of current contributions on savings is by construction different from one. Misinformation about retirement benefits results in the individual's failure to recognize that the pension system is balanced. The rate of return of the pension contributions implied by the individual's expectations on pension benefits is given by the ratio $\gamma_{it} = \sum_{s=R+1}^{T} E_{it}B_s / \sum_{s=1}^{R} d_s$, which is less than one if benefits are underestimated. Substituting back in (12), we obtain

$$s_t = y_t - \left(1 + \frac{\gamma_{it} - 1}{T - (t-1)}\right) d_t - \frac{1}{T - (t-1)} \left[A_t + \sum_{s=t}^{R} y_s - (1 - \gamma_{it}) \sum_{s=t+1}^{R} d_s + \gamma_{it} \sum_{s=1}^{t-1} d_s\right] \tag{3.13}$$

where the displacement effect of *current* contributions is equal to $1 + \frac{\gamma_{it}-1}{T-(t-1)}$. A numerical example helps clarify this point. Suppose that, given his information set, an individual overestimates his benefits and believes that the internal rate of return is equal to 3, i.e. \$1 of contributions paid while working are worth \$3 of pension wealth. Then, first of all savings are reduced by \$1, i.e. the amount of contributions paid in a given year. This is the pure offset effect due to the fact that the system transfers individual's resources from the working years to the retirement years. There is however another channel through which contributions affect savings. Due to misinformation, for each dollar of contributions actually paid, the individual expects to receive from the system at retirement \$2 as pure transfers, i.e. $\gamma_{it} - 1$. This transfer constitutes additional resources that can be consumed, so that savings are further reduced by an amount equal to the marginal propensity to consume into the amount of the perceived future transfer. In other words, $\frac{\gamma_{it}-1}{T-(t-1)} d_t$ represents the amount of current consumption financed with pension wealth that the individual perceives to be transferred to him without having contributed for. The displacement effect is therefore greater than one if individuals tend to hold optimistic expectations about their pension wealth, or less than one if pessimism prevails.

Gale and Scholz (1994) obtain an estimate of the substitution between IRA and non-IRA savings by allowing the offset effect to vary with individual characteristics. As they implicitly assume that individuals know the rate of return on their IRA savings, and this is constant across the sample, they do not consider the issue of heterogeneity in the 'perceived' rate of return, and interpret the variation in the estimated offset effect as cross-sectional heterogeneity in time discount rate or in transaction costs, in case of an asset reshuffling.

It is still possible, however, to test for the offset hypothesis with a methodology similar to the one used by Gale. Using a structural model as in Gale, one can construct the adjustment factor $1 + \frac{\gamma_{it}-1}{T-(t-1)}$, multiply the contribution variable by this factor and test whether the estimated coefficient on the adjusted contribution variable is different from one.[12] The problem with this approach, however, is that it is essential to have accurate data on past and expected future contributions. If expectational errors are correlated with the size of pension coverage, then γ_t (and therefore the constructed adjusted contribution variable) is correlated with $\{d_s\}_{s=1}^{R}$.

3.3.3 Misinformation and Projected Wealth at Retirement

Finally, in this section we turn to show how it is still possible to test for the offset effect by looking at the sustitutability between private wealth and pension wealth using *projected* wealth holdings in place of *current* wealth. Formally, let us consider again the situation outlined in Section 3.1. The individual has accumulated wealth A_t' at the beginning of period $t > \tau$, where τ is the age at which he updated his expectations about retirement benefits. As previously seen, such wealth depends on past expectations on retirement benefits and on the timing of information updating. His optimal planned consumption in any period

[12]Note that this approach should be followed even in those cases when individuals have perfect knowledge about their retirement benefits, but the pension system is not actuarially fair and it is redistributive, in the sense that individuals have different internal rates of return.

$s = t, ..., T$ is given by

$$C''_s = \frac{1}{T-(t-1)}\left[A'_t + \sum_{s=t}^{R}(y_s - d_s) + \sum_{s=R+1}^{T} B_s\right] \tag{3.14}$$

which is equivalent to eq.(8) with the exception that we are now using beginning of period wealth A'_t to "summarize" past expectations as well as past consumption behavior. The wealth he plans to accumulate at retirement is given by

$$A_{R+1} = A'_t + \sum_{s=t}^{R}(y_s - d_s) - \frac{R-(t-1)}{T-(t-1)}\left[A'_t + \sum_{s=t}^{R}(y_s - d_s) + \sum_{s=R+1}^{T} B_s\right].$$

Rearranging terms, we obtain

$$A_{R+1} = (1-c_t)\,A'_t + \sum_{s=t}^{R}(y_s - d_s) - c_t\left[\sum_{s=t}^{R}(y_s - d_s) + \sum_{s=R+1}^{T} B_s\right]. \tag{3.15}$$

where $c_t = \frac{R-(t-1)}{T-(t-1)}$ and it represents the portion of lifetime resources that the individual plans to consume over the remaining working years. Note that eq.(15) is similar to eq.(5), though now we take into account the effect of past expectational errors and information updating through the wealth already accumulated up to t and that will be saved for the retirement years, i.e. $(1-c_t)\,A'_t$. Let $\widetilde{A}_{R+1} = A_{R+1} - (1-c_t)\,A_t$; this represents a 'normalized' wealth, i.e. the wealth that an individual plans to accumulate by age $R+1$, being born at age $R-(t-1)$ with no initial wealth. There is an obvious correspondence between $\widetilde{A}_{R+1}$ and A_{R+1} in eq.(5).

From an empirical point of view, if one can obtain a measure of the private wealth an individual plans to hold before entering retirement, then it is possible to test for the offset hypothesis using eq.(15) without incurring the endogeneity problem arising when using the traditional specification of wealth equations. Even in this case, a model that incorporates perfect offset of pension wealth on private wealth generates an offset that is by construction different from one. However, by correcting the pension wealth variable with the appropriate adjustment factor c_t, it is still possible to test for perfect offset. In the next section we propose a methodology to obtain a measure of planned wealth at retirement and compute the adjustment factor in a more general framework with income uncertainty and isoelastic preferences.

Note that this approach exploits the role of current wealth holdings as a "sufficient statistic." From eq.(10), current wealth is a function of both past information sets (B_s') and the economic decisions previously taken by the individuals (α_1,α_2). Eq.(15) shows that once we condition on A_t', then sample information on past expectational errors and information updating is no longer required to obtain an unbiased estimate of the offset effect.

3.4 Econometric Model

In this section we describe the econometric specification used to test for perfect offset on projected wealth. Consider an individual i with a vector of demographic characteristics X_i. Life span is deterministic and equal to T. Let y_{is} be the uncertain income net of pension contributions during the working periods. The income follows the process $y_{it} = E_{it-1}y_{it} + \nu_t + \eta_{it}$, where ν_t is a macroeconomic shock and η_{it} an idiosyncratic shock. Let $\{I_{is}\}_{s=t}^{T}$ be an indicator variable for the labor status of the individual, i.e. it is equal to 0 if the individual works in period s, and to 1 if the individual is retired. Let $E_{it}PW_{it}\left(\{I_{is}\}_{s=t}^{T}\right)$

be the discounted value of the pension wealth as expected by the individual. Pension wealth depends typically on the individual's retirement age according to the rules of the pension system. Here we do not model explicitly a specific pension system, but simply acknowledge that pension wealth depends on the chosen sequence of labor states.

In every period the individual decides the consumption stream and the sequence of labor states, conditional on the information available at time t and taking into account the economic incentives of the pension system. Formally, at time t (which also indicates the individual's age) his optimization problem is

$$\max_{\{C_{is},I_{is}\}_{s=t}^{T}} E_{it}\left[\sum_{s=1}^{T}\frac{1}{1+\delta X_i}u\left(C_{is}\right)\right]$$

$$\text{s.t. } E_{it}\left[\sum_{s=t}^{T}\left(\frac{1}{1+r_i}\right)^{s-t}C_{is}\right]=A_{it}+\sum_{s=t}^{T}\left(\frac{1}{1+r_i}\right)^{s-t}\left(E_{it}y_{is}\right)^{1-I_{is}}+E_{it}\left[PW_{it}\left(\{I_{is}\}_{s=t}^{T}\right)\right] \tag{3.16}$$

where we allow the discount rate to depend on individual characteristics and r_i is the deterministic interest rate. We assume isoelastic utility, in particular

$$u\left(C_{is}\right)=\frac{\exp\left(\theta I_{is}\right)}{1-\rho X_i}C_{is}^{1-\rho X_i} \tag{3.17}$$

The term θI_{is} captures the way the retirement status scales within-period consumption, while ρX_i represents the individual-specific coefficient of relative risk aversion. Let $\{E_{it}C_{is}, E_{it}I_{is}\}_{s=t}^{T}$ be the solution to the above problem, i.e. $E_{it}C_{is}$ and $E_{it}I_{is}$ are the consumption and labor state at time s as planned by the individual at time t given the information set of time t. We now turn to show how to obtain i) a relation linking planned wealth at retirement and expected pension wealth, and ii) a measure of planned wealth at retirement.

Relation Between Planned Wealth at Retirement and Expected Pension Wealth. The optimal path of consumption satisfies the following Euler Equation

$$E_{it}\left(\triangle \ln C_{is+1}\right) = \theta E_{it}\left(\triangle I_{is+1}\right) + \frac{1}{\rho X_i}\left(r - \delta X_i\right) + \frac{\rho X_i}{2} var\left(\triangle \ln C_{is+1}\right). \tag{3.18}$$

By substituting recursively in the budget constraint the identity $E_{it}C_{is} \equiv \prod_{j=t+1}^{s}\left(1 + E_{it}\left(\triangle \ln C_{ij}\right)\right) C_{it}$, we obtain the following consumption function

$$C_{it} = c_{it}\left[A_{it} + \sum_{s=t}^{T}\left(\frac{1}{1+r}\right)^{s-t}\left(E_{it}y_{is}\right)^{1-E_{it}I_{is}} + E_{it}\left[PW_{it}\left(\{I_{is}\}_{s=t}^{T}\right)\right]\right] \tag{3.19}$$

where c_{it} is the marginal propensity to consume and it is a function of expected future consumption growth rates and lifetime span, i.e. $c_{it} = c\left(E_{it}\left(\triangle \ln C_{is}\right), T\right)$. The empirical counterpart of this consumption function is $\widetilde{C}_{it} = C_{it} + \omega_{it}$ where $\widetilde{C}_{it}$ is observed consumption and ω_{it} has been interpreted in the literature as a measurement error.

Let R_{it} be planned retirement age based on the planned sequence of labor states. Consider now the following identity: planned wealth at retirement is equal to current wealth holding plus expected future incomes up to retirement minus expected future consumption

$$E_{it}\left(A_{iR_{it}}\right) \equiv A_{it} + \sum_{s=t}^{R_{it}-1}\left(\frac{1}{1+r_i}\right)^{s-t} E_{it}y_{is} - \sum_{s=t}^{R_{it}-1}\left(\frac{1}{1+r_i}\right)^{s-t} E_{it}C_{is} \tag{3.20}$$

Given that $E_{it}C_{is} = \prod_{j=t+1}^{s+1}\left(1 + E_{it}\left(\triangle \ln C_{ij}\right)\right)\widetilde{C}_{t}$, and substituting the empirical consumption function, we obtain

$$\begin{aligned} E_{it}\left(A_{iR_{it}}\right) &= g_1(\cdot)\,A_{it} + g_2(\cdot)\sum_{s=t}^{R_{it}-1}\left(\frac{1}{1+r_i}\right)^{s-t} E_{it}y_{is} - \\ &\quad -g_3(\cdot)\,E_{it}\left[PW_{it}\left(R_{it}\right)\right] - g_4(\cdot)\,\omega_{it} \end{aligned} \tag{3.21}$$

where $g_k(\cdot) = g_k\left(E_{it}\left(\triangle \ln C_{is}\right), T\right)$. If this equation is estimated conditioning on current wealth holdings and future expected incomes, then the expected pension wealth variable is uncorrelated with the error term and no endogeneity problem arises because of past expectational errors. The key problem is to obtain a measure of planned wealth at retirement, given that is tipically not available in datasets.

Measure of Planned Wealth at Retirement. The procedure we follow to obtain a measure of planned wealth at retirement is to 1) estimate a consumption growth equation to obtain the predicted path for consumption, and 2) use eq.(20) to construct the variable of interest. We estimate the following second-order linear approximation of the Euler Equation

$$\triangle \ln C_{it+1} = \beta_1 \triangle I_{it+1} + \beta_2 r_i + X_{it}\beta_3 + X_{it}\left(\triangle \ln C_{it+1}\right)^2 \beta_4 + \varepsilon_{it+1}, \tag{3.22}$$

since we do not have a long panel, and it is impossible to obtain accurate estimates of the structural parameters. $\triangle I_{it+1}$ and $\left(\triangle \ln C_{it+1}\right)^2$ are endogenous variables. Since ε_{it} is an expectational error, and given the structure of the income process, legitimate instruments are variables dated t. For the variance of the consumption growth, we follow Jappelli and Pistaferri (2000) and proxy it with the expected variance of income growth σ^2_{it+1}. This is reasonable in this framework since the only source of uncertainty is income risk.

Given the estimated parameters $\widehat{\beta}$ and expectations on future variables $E_{it}\left(Z_{is+1}\right) = \left[E_{it}\left(\triangle I_{is+1}\right), E_{it}\left(X_{is+1}\right), E_{it}\left(\sigma^2_{is+1}\right)\right]$, we can predict the future path of expected consumption growth rates $E_{it}\left(\widehat{\triangle \ln C_{is+1}}\right) = f\left(E_{it}\left(Z_{is+1}\right); \widehat{\beta}\right)$. Using eq.(20), planned wealth at retirement is

$$E_{it}\widehat{\left(A_{iR_{it}}\right)} \equiv A_{it} + \sum_{s=t}^{R_{it}-1}\left(\frac{1}{1+r_i}\right)^{s-t} E_{it}y_{is} - h\left(E_{it}\left(Z_{is+1}\right); \widehat{\beta}\right)\widetilde{C}_{it} \tag{3.23}$$

It is important to underline that the measure of planned wealth so obtained does not satisfy eq.(21) by definition. $E_{it}\widehat{\left(A_{iR_{it}}\right)}$ is obtained using the identity (20), that links wealth, income and consumption, the estimated consumption growth rates and *actual* consumption. Eq.(21) is instead obtained from the same identity but using the consumption function that theoretically links current consumption to expected pension wealth. The difference between eq.(21) and (23) is therefore that the former is true conditional on the individuals consuming a portion of their currently expected pension wealth that is consistent with the above life-cycle model, while the latter is based only on a accountancy identity and an estimated intertemporal relation of consumption.

Note that the error term in eq.(21) is a function of $g_4(\cdot)$, which is individual specific and it is potentially correlated with the regressors. Using the estimates of $E_{it}\left(\widehat{\triangle \ln C_{is+1}}\right)$, we compute all the functions $g_k(\cdot)$, construct the following variables

$$\begin{aligned}
\widehat{A}_{iR_{it}} &= \frac{E_{it}\widehat{(A_{iR_{it}})}}{g_4} \\
\widehat{A}_{it} &= A_{it}\frac{g_1}{g_4} \\
\widehat{Y}_{it} &= \frac{g_2}{g_4}E_{it}\sum_{s=t}^{R_{it}-1}\left(\frac{1}{1+r}\right)^{s-t} y_{is} \\
E_{it}\left[\widehat{PW_{it}(R_{it})}\right] &= \frac{g_3}{g_4}E_{it}\left[PW_{it}(R_{it})\right]
\end{aligned}$$

and estimate the following equation

$$\widehat{A}_{iR_{it}} = \alpha_1\widehat{A}_{it} + \alpha_2\widehat{Y}_{it} + \alpha_3 E_{it}\left[\widehat{PW_{it}(R_{it})}\right] - \omega_{it} \tag{3.24}$$

This equation allows us to test whether individuals substitute private wealth and pension wealth in a way that is quantitatively consistent with the life cycle model. If the life-cycle model outlined above holds, than every individual reduces planned private wealth at retirement by an amount equal to $\frac{g_3}{g_4}$ for every dollar of pension wealth. Hence the coefficient α_3 should be equal to minus one.

3.5 Data

We use data drawn from the Bank of Italy Survey of Household Income and Wealth (SHIW). This dataset has been extensively used to test several life cycle theory predictions, including the perfect offset effect. Jappelli (1995) adopts an econometric specification based on current wealth holdings and a measure of social security wealth obtained from individual expectations on the retirement age and the replacement rate, i.e. the ratio of expected first benefits' payment over expected last monthly income. He finds that the offset effect for Italian households is about 11-16%. When instrumenting social security wealth through legislated retirement age and replacement rate, he finds a significantly higher offset effect (about 20%), hence concluding that endogeneity of the social security wealth variable may be an important issue.

For this dataset it is not possible to link the observations with Social Security Administration records, so that it is impossible to check whether the type of misinformation documented for the US applies also for Italy. We can however speculate that this is the case. The Italian Social Security system is unfunded and incorporates more than 50 different funds for different workers' categories and occupations. Even though eligibility rules and retirement benefits varies substantially across the funds, most of them operated using the following rule until 1992: yearly benefits are a percentage of the average yearly income over the *last* working years, where the percentage is a linear function of the years of contributions (up to a maximum).[13] The number of years over which the average yearly income is calculated depends on the fund, but it can be as low as 5 years. Individuals at an early stage in their career and with riskier jobs in terms of higher income variability, may clearly find it pointless to gather accurate information about their future retirement benefits, that will be based in any case on future income, which can only be noisily predicted. In trading off between the cost of acquiring information and making calculations, and the accuracy of expectations (which cannot be very high anyway), these individuals are likely to give up and choose to be misinformed, or make their best bet based on some rule of thumb.

[13] In 1992 and 1995 two major reforms took place that changed the system from an unfunded one to a fully funded one. Since we use data for the period 1989-1991, we are concerned on how misinformation affected the private wealth accumulation path before these reforms.

These individuals are however likely to: 1) update their information over time as their career settles and income volatility decreases, making it worth to become informed, 2) have higher Social Security wealth, since there is typically a positive correlation between income risk and future income growth, and their pension benefits are computed based on the latest incomes.[14]

This leads to think that even in Italy there may be a correlation between social security wealth and expectational errors, and timing of information updating. Part of this endogeneity may have been already detected by Jappelli when he instruments social security wealth. His finding of a significantly higher offset effect, when social security wealth is instrumented, is consistent, in our framework, with a downward bias due to a tendency to underestimate retirement benefits. Such a pessimistic attitude may also be behind the well documented high saving rate of Italian households, and the existence of a precautionary motive for saving as found in Jappelli and Pistaferri (2000).

We now turn to describe how we construct some crucial variables. The strength of this data set is that it contains subjective expectations about income growth and variance, as well as information on the replacement ratio, that allow us to construct accurate measures of expected future earnings and expected social security wealth.

3.5.1 Euler Equation

The SHIW is a bi-annual survey and has a panel component. We estimate the Euler Equation pooling the panels of the waves 1989-91 and 1991-93, which means that we can

[14]Apart from personal attitudes toward risk, individuals are more willing to accept a highly variable income stream today if it is going to pay in the future in terms of higher average income.

only observe the consumption growth rate over two years. These panels include 5,657 households. By dropping observations with inconsistent information on sex and age of the head of household, or with missing data on employment status, expected retirement age, or expected income variance, we remain with 3580 observations.

We estimate two versions of the Euler equation, one for non-durable consumption growth and the other for total consumption. In both cases we control for changes in the labor status of the household head, as well as for the spouse. We therefore construct a categorical variable equal to 1 if the household head made the transition from work to retirement between period t and $t+1$ of our panel (i.e. over two calendar years), and zero otherwise. Since there is no individual who made the transition from retirement to work, we do not control for such a labor status change, which is consistent with retirement being an absorbing state in the Italian system. For the spouse, there seems to be more variation with transitions in and out of the labor force, not necessarily involving retirement. We therefore construct two indicator variables, one is equal to 1 if the spouse made the transition out of the labor force and zero if not, and the other is equal to 1 if the spouse made the transition into the labor force and zero otherwise. The expected real interest rate is constructed by subtracting household inflation expectations from the nominal interest rate on government bonds.

3.5.2 Wealth Equation

For the wealth equation we pool the 1989 and 1991 cross-sections, since we do not need repeated observations. Initially we have 16,462 households. Excluding observations where the household head was more than 45 years old, was already retired at the time of the interview, had missing information on expected retirement age, income growth and its variance, we remain with 2,329 observations (1,372 for the 1989 wave, and 1957 for the 1991 wave).

In order to obtain a measure of planned wealth at retirement we need to forecast the expected future consumption growth rates, based on the Euler equation estimates and the future expectations on variations in family composition. To do this we use the 1993-95 panel, since the 1995 wave elicits information on family members that left the household during the last two years. We therefore consider the pool of family members who left the household between 1993 and 1995 because they started a new household, and regress their age over sex and other household characteristics, such as household head education and a dummy for the working spouse. We then use this estimates to predict the age at which household members of our study sample are expected to leave the household, and therefore the pattern of consumption growth rates. We then compute the factors g_{it} and c_{it} based on expected retirement age.

To compute the expected present value of the future stream of household disposable income, net of pension contributions, we use the information on the growth rate of income as expected by the household head and its spouse, if applicable, and use it along with current consumption and asset holdings to construct wealth at retirement. We use both current total consumption and non-durable consumption with the respective expected consumption growth rates predicted from the estimated Euler equations. The measure of current wealth used includes all real assets net of financial liabilities. Finally, to test for the offset effect, we construct the expected social security household wealth variable using the income profiles as expected by the household and his spouse, and their expected replacement ratios.

3.6 Results

3.6.1 Euler Equation Estimates

In this section we discuss the estimation results for the Euler equation. Since the change in labor status of the household head as well as of the spouse can be correlated with income shocks affecting the consumption growth rate, we need to instrument them. In Table 2 we present the results of the first stage regressions for a) the transition of the household head from work to retirement, b) the transition of the spouse out of the labor force, c) the transition of the spouse into the labor force. In all these equations we cannot use time dummies as well as dummies related with the sector of activity since they may be picking up macroeconomic shocks affecting also the consumption growth rate.

In the equation for the household head's transition from work to retirement, we use the expected change in the labor status as instrument, i.e. a variable equal to 1 if at time t the head planned to be retired at $t+1$, and zero otherwise. Since this reflects expectations as of time t, it is not correlated with the shock in the growth rate of consumption. We find that the expected labor status change has a positive and significant effect on the actual labor status change. Controlling for unemployment status as of time t we find that those who are unemployed at time t are significantly more likely to retire by next period. Furthermore, the probability of making the transition is positively related with the number of income receivers in the family.

For the spouse's changes in labor status we use education dummies, number of income receivers, number of family members and number of children aged less than 18 (all variables dated t) as instruments. We find that the number of income receivers significantly increases the probability for the spouse to exit the labor force, while it decreases the probability to enter the working status, after controlling for age. The number of family members, on the other side, has a negative and significant effect on the exit probability and a positive and significant effect on the work probability. The effects of both variables on the entry and exit probabilities are consistent with an income effect on the spouse's leisure. The higher is the number of family members already working (and likely the higher is the family income), or the higher is the 'per capita' income of each family member (controlled for through the number of family members), then the spouse is more likely to exit and less likely to entry. We also estimated the same equations using the percentage of family members who are income receivers and the results were confirmed.[15]

Table 3 shows the results when estimating the euler equation using the growth rate of non-durable consumption (column (a)) and of total consumption (column (b)). The household head transition from work to retirement has a negative and significant effect on the growth rate of non-durable and total consumption, consistently with a leisure-consumption substitution effect at retirement. On the contrary, if the spouse makes the transition into the working status, the consumption growth rate increases, which can be interpreted in light of an income effect on consumption. If the spouse exits the labor force, this has a negative and significant effect on the growth rate of total consumption only, while the growth rate of non-durable consumption is unaffected. This may be due to the fact that the spouse decision of retiring or becoming a housewife may be taken after the household has ensured the planned level of non-durable expenditures, while the trade off between consumption and

[15]We also controlled for changes in the age structure of the family members, but they were not significant (results not shown).

spouse's leisure is made over durable consumption goods.

Expected income variance is positively and significantly affecting the consumption growth rate only for non-durable consumption and the coefficient is close in magnitude to the one estimated in Jappelli and Pistaferri (2001). Finally, changes in family composition and in the number of income receivers have also a significant and positive impact on both growth rates.

3.6.2 Wealth Equation Estimates

In Table 4 we report the estimated coefficients of the wealth equation when projected wealth at retirement is computed using total consumption. In column (a) we simply regress projected wealth on current asset holdings, future income and social security wealth, omitting the constant. The coefficients on current wealth and future income are both very high and significantly different from one, while the offset effect is equal to -0.43. This offset is significantly lower then what theory would predict, but higher than previous estimates obtained by Jappelli. In column (b) we interact the three variables with an age dummy identifying the younger workers aged 45-54. The estimate of the offset effect for the older workers is -0.52, while for younger workers is significantly lower -0.17. The fact that younger workers have a lower offset effect may be explained by precautionary attitudes: they recognize that their information on future retirement benefits is limited and plan to consume over the working years a portion of their social security wealth lower than what the life-cycle model would predict, therefore carrying higher wealth into retirement. Note furthermore that younger workers carry also higher portions of their current wealth holdings and expected future income into retirement than older workers. This too may be explained by a precautionary motive in response not to income uncertainty (which has been considered explicitly through the consumption growth that includes the effect of perceived income risk), but to a more general uncertainty over future events. To explore further this idea we interact all the variables with the difference between the expected retirement age of the household head and his age. The results in column (c) show that while the expected number of years before retirement significantly affects the offset effect (workers further away from their retirement have a lower offset effect), it does not have an impact on the coefficients of current wealth and future income, after controlling for age. This seems to suggest that while for the social security wealth it is the uncertainty related to the retirement benefits themselves that matters (and therefore the time horizon over which this uncertainty is not resolved), for current wealth and future income is uncertainty related with age independently of when the individual plans to retire. In column (d) we report the estimates when adding the interactions of the three main variables with a dummy equal to 1 if the household owns the house and zero otherwise and with a dummy indicating whether the household pays a mortgage. The presence of a mortgage has no effect, while house ownership negatively affects the amount of current wealth and future income the household plans to carry onto retirement. Finally in the last column we add the interaction with the number of children present in the household, but again this affects in a positive way only the amount of current wealth and income carried into retirement, while it does not affect the offset effect.

We repeat the analysis considering only non-durable consumption and its growth rate, the results are shown in Table 5. The main differences are that now the coefficients on current wealth and future income are higher, while the offset effect is lower, across all specification; furthermore the presence of a mortgage has a significant positive effect on retirement wealth.

Across all specifications and independently of the definition of consumption we use, we find that the offset effect is significantly lower than one, while the household carries over into retirement more current wealth and future resources than what the life-cycle model predicts. Both these facts may be consistent with a precautionary behavior towards uncertain events beyond income risk.

3.7 Conclusions

In this paper we identify several problems that researchers may encounter when estimating the offset effect of pension wealth over private wealth, if individuals make expectational errors about their retirement benefits and these errors are correlated with their entitlements. We propose an alternative methodology that overcomes these problems and apply it to an Italian data set. The estimates of the offset effect we obtain are higher than what previously found using the same data, but still are significantly below perfect substitution. We argue that this may be due to precautionary behavior in response to uncertainty about future benefits: individuals may be aware that their expectations may be erroneous and have higher private savings. This seems confirmed by the fact that for workers closer to their expected retirement benefits the estimated offset effect is higher: these workers may be more confident about their knowledge of the pension system and about the precision of their expectations.

An interesting and related result concerns the way household behaves in terms of carrying current private wealth and future income as retirement wealth. Our estimates show that households have even in this case a conservative behavior, carrying more resources than what life-cycle models would predict. Part of this over-accumulation of wealth may be explained by the need to buy a house, or the desire to leave bequests to their children, but even after controlling for this factors there is a substantial unexplained over-accumulation. Again, this can be consistent with precautionary behavior towards uncertain events.

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Table 1: Knowledge about Retirement Benefits

$\frac{\text{Expected Benefits}}{\text{Actual Benefits}}$ Social Security

$\frac{\text{SS Wealth}}{\text{Total Wealth}}$	All Sample				Sample with Expected Benefits		
	<75%	75-125%	>125%	DK	<75%	75-125%	>125%
0-20%	**19.8**	26.2	12.4	41.6	33.9	44.9	21.2
20-40%	**12.8**	31.0	9.5	46.7	24.0	58.2	17.8
40-60%	**11.1**	30.0	8.2	50.7	22.5	60.9	16.6
>60%	**13.5**	19.0	9.3	58.2	32.3	45.5	22.2

$\frac{\text{Expected Benefits}}{\text{Actual Benefits}}$ Pension

$\frac{\text{Pension Wealth}}{\text{Total Wealth}}$	All Sample				Sample with Expected Benefits		
	<75%	75-125%	>125%	DK	<75%	75-125%	>125%
0-20%	**20.7**	12.1	22.3	44.9	37.6	22.0	40.4
20-40%	22.7	15.9	18.4	43.0	39.8	27.9	32.3
40-60%	29.0	21.3	10.7	39.1	47.6	34.9	17.5
>60%	43.9	18.4	8.7	29.1	61.8	25.9	12.3

Source: Gustman and Steinmeier (2001).

Table 2: Instrumenting Labor Status Changes: First Stage Regressions

	Dep. Var.:	(a) $\triangle$Working Head	(b) $\triangle$Spouse out	(c) $\triangle$Spouse in
Expected ($\triangle$Working Head)		1.342*** (0.00)		
Age		.394*** (0.00)		
Age^2		-.003*** (0.00)		
Unemployed in t		2.89*** (0.00)		
Unmarried		.028 (0.87)		
Number of income receivers		.191*** (0.00)	0.218*** (0.00)	-.499*** (0.00)
Number of family members		-.088 (0.22)	-.108** (0.03)	.099** (0.04)
Number of children (aged <18)		-.028 (0.76)	-.0105* (0.10)	-.187*** (0.00)
Spouse Age			.013 (0.55)	.015 (0.46)
Spouse Age^2			.000 (0.61)	.000 (0.41)
	Observations	3580	2907	2907
	Log likelihood	-349.00	-688.53	-580.91
	Pseudo R^2	.44	.04	.06

* denotes significance at the 10% level; ** 5% level; and *** 1% level.

P-values in parentheses, computed from robust standard errors. Constant included.

(a) We also control for education and qualification dummies (blue collar, white collar, professional, self-employed)

(b) - (c) We also control for education dummies

Table 3: Euler Equation

	Dep. Var.:	(a) $\triangle$Ln(Non-Dur. Consump)	(b) $\triangle$Ln(Tot. Consump)
Age		.002***	.002***
		(0.01)	(0.00)
$\triangle$Working Head		-.248***	-.189***
		(0.00)	(0.01)
$\triangle$Spouse out		-.160	-.341**
		(0.33)	(0.05)
$\triangle$Spouse in		.669***	.618***
		(0.00)	(0.00)
Expected income variance		4.259**	.369
		(0.03)	(0.88)
Expected real interest rate		-.191	-.268
		(0.21)	(0.11)
$\triangle$Number of family members		.119***	0.111***
		(0.00)	(0.00)
$\triangle$Number of income receivers		.086***	.103***
		(0.00)	(0.00)
	Observations	3580	3580

* denotes significance at the 10% level; ** 5% level; and *** 1% level.

P-values in parentheses, computed from robust standard errors. Constant included.

(a) - (b) We also control for education, qualification (blue collar, white collar, professional, self-employed), region, time dummies, and the interaction of region and time dummies.

Table 4: Asset Equation (Total Consumption)

	(a)	(b)	(c)	(d)	(f)
A_t	1.867***	1.532***	1.436***	1.459***	1.267***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
A_t*(45-54)		.132***	.109***	.097**	.083***
		(0.00)	(0.00)	(0.03)	(0.03)
A_t*(R-Age)			.006		
			(0.45)		
A_t*Home Owner				-.135***	-.125***
				(0.00)	(0.00)
A_t*Home Owner*Mortgage				.003	
				(0.47)	
A_t*No.Children					0.121***
					(0.00)
Income	1.294***	1.176***	1.154***	1.152***	1.103***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Income*(45-54)		0.039***	.037***	.029***	.027***
		(0.00)	(0.00)	(0.00)	(0.00)
Income*(R-Age)			.009*	.013	
			(0.10)	(0.24)	
Income*Home Owner				-.035***	-.036***
				(0.00)	(0.00)
Income*Home Owner*Mortgage				.032	
				(0.47)	
Income*No.Children					.028*
					(0.08)
SSW	-.438***	-.527***	-.536***	-.512***	-.511***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
SSW*(45-54)		.358***	.013		
		(0.00)	(0.23)		
SSW*(R-Age)			.237***	.254***	.232***
			(0.00)	(0.00)	(0.00)
SSW*Home Owner				-.027	
				(0.67)	
SSW*Home Owner*Mortgage				.347	
				(0.82)	
SSW*No.Children					1.023
					(0.74)
Observations		2329	2329	2329	2329

* denotes significance at the 10% level; ** 5% level; and *** 1% level.

P-values in parentheses, computed from robust standard errors.

Table 5: Asset Equation (Non-durable Consumption)

	(a)	(b)	(c)	(d)	(f)
A_t	1.956***	1.765***	1.645***	1.468***	1.357***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
A_t*(45-54)		.054***	.052***	.132***	.114***
		(0.00)	(0.00)	(0.00)	(0.03)
A_t*(R-Age)			.000		
			(0.73)		
A_t*Home Owner				-.458***	-.452***
				(0.00)	(0.00)
A_t*Home Owner*Mortgage				.056***	.049***
				(0.00)	(0.00)
A_t*No.Children					0.348***
					(0.00)
Income	1.472***	1.263***	1.232***	1.214***	1.207***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Income*(45-54)		0.126***	.123***	.093***	.089***
		(0.00)	(0.00)	(0.00)	(0.00)
Income*(R-Age)			.008		
			(0.30)		
Income*Home Owner				-.165***	-.166***
				(0.00)	(0.00)
Income*Home Owner*Mortgage				.117***	.115***
				(0.01)	(0.01)
Income*No.Children					.249***
					(0.00)
SSW	-.356***	-.489***	-.456***	-.498***	-.472***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
SSW*(45-54)		.278***	.016		
		(0.00)	(0.54)		
SSW*(R-Age)			.263***	.278***	.274***
			(0.00)	(0.00)	(0.00)
SSW*Home Owner				-.148	
				(0.69)	
SSW*Home Owner*Mortgage				1.894	
				(0.54)	
SSW*No.Children					1.589
					(0.96)
Observations		2329	2329	2329	2329

* denotes significance at the 10% level; ** 5% level; and *** 1% level.

P-values in parentheses, computed from robust standard errors.